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770804

DATE: August 1, 1977

SUBJECT: A Study of Low-Level Radioactive Solid Waste Disposal and Storage Areas at the Oak Ridge National Laboratory

TO: Distribution

FROM: J. O. Duguid, D. E. Edgar, J. R. Gissel, R. A. Robinson

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LIST OF TABLES

LIST OF FIGURES

Figure		Page

TABLE OF CONTENTS

Page

I. SITE CHARACTERISTICS

A. Description

1. Physiography

The Oak Ridge Reservation is located in Roane and Anderson counties, Tennessee. The area is situated within the Tennessee or southern section of the Ridge and Valley Province (Fig. 1), of the Appalachian Highlands Division (Fenneman, 1938; Thornbury, 1965). This physiographic province, sometimes called the "Newer Appalachians", is characterized by the following geomorphic features (Thornbury, 1965): (1) marked parallelism of ridges and valleys, commonly trending in a northeast-southwest direction; (2) conspicuous influence of alternating strong and weak stratigraphic units upon topographic forms; (3) a few major transverse streams with significant development of subsequent drainage producing a trellis drainage pattern in most areas; (4) general accordance of summit levels; and (5) abundant water and wind gaps through resistant rock ridges indicating past cases of stream diversion.

Present Ridge and Valley topography is thus the result of differential erosion of alternating weak and resistant strata folded into a series of anticlines and synclines. Valleys are of variable width and bounded by steep slopes ascending to the adjacent, parallel ridges which are locally 200 to 500 feet high. Thus a hilly, rolling topography of moderate relief is indicative of the area (see Fig. 3).

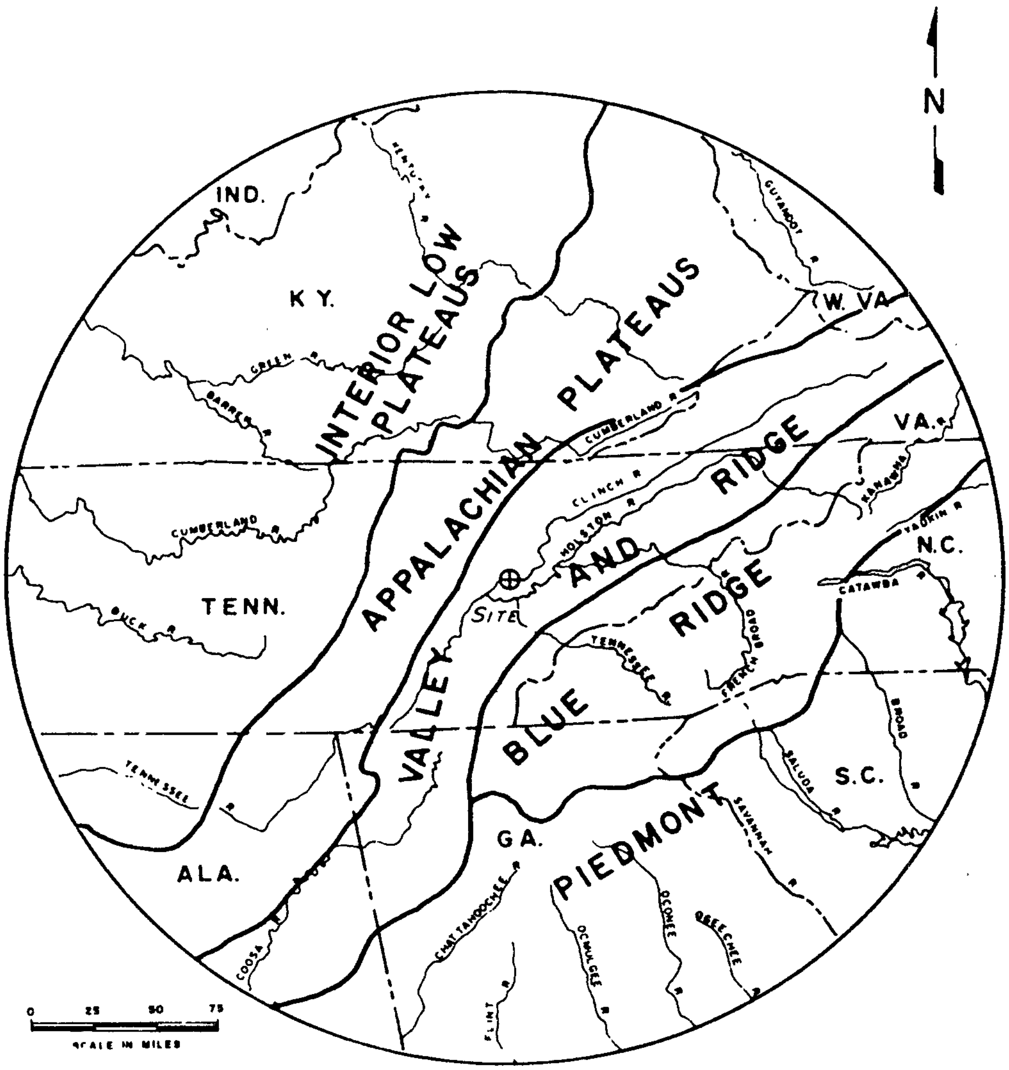

Fig. 1. Regional physiographic map of eastern Tennessee and surrounding area (from CRBRP-ER).

In the immediate vicinity of the Oak Ridge Reservation, the succession of alternating ridges and valleys from southeast to northwest is as follows: Copper Ridge, Melton Valley, Haw Ridge, Bethel Valley, Chestnut Ridge, Bear Creek Valley, Pine Ridge, Gamble Valley, East Fork Ridge, East Fork Valley, and Black Oak Ridge. Each of the ridges attains elevations in excess of 1200 feet, whereas the valley bottoms range in elevation from 741 feet at the Clinch River to over 900 feet (Stockdale, 1951). The maximum elevation in the X-10 area is 1,356 feet at Melton Hill, located on Copper Ridge (McMaster, 1953). Thus the maximum local relief is 615 feet. Most of ORNL is within Bethel Valley with some facilities being sited in Melton Valley.

Bethel Valley is a portion of an elongated, northeast-southwest trending trough developed upon a belt of non-resistant limestones and shaly limestones of the Chickamauga Formation. The Bethel Valley portion of this trough is seven and one-half miles long and the floor has an average width of 1,000 feet. The lowest point of the valley floor near ORNL is where White Oak Creek passes through Haw Gap at 770 feet elevation (Stockdale, 1951).

That part of Bethel Valley near the X-10 site is drained by White Oak Creek and its tributaries (Figs. 2 and 3). White Oak Creek heads on Chestnut Ridge a short distance northeast of ORNL and flows through the southern portion of the Laboratory proper. Immediately south of the Laboratory the creek passes through a watergap in Haw Ridge and thence flows south-southeastward in Melton Valley where it is joined by Melton Branch. The drainage is impounded by an earth dam where Tennessee Highway 95 crosses the channel approximately one-half mile above the

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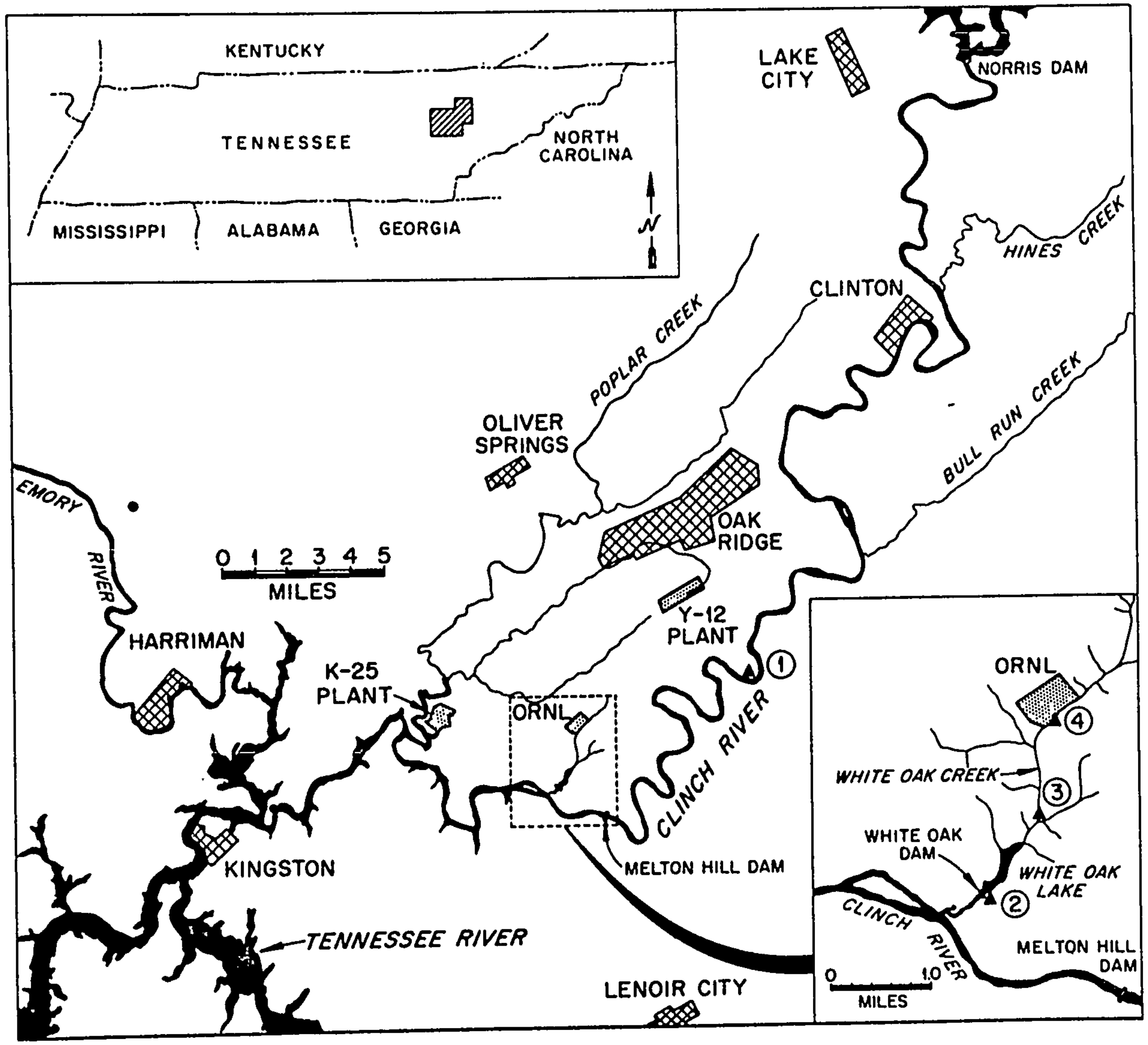

Fig. 2. Location map of USERDA Reservation and surrounding area, Oak Ridge, Tennessee (from USAEC, 1974).

stream mouth. The dam and release gate (elevation 750 feet at top) form a small, shallow reservoir called White Oak Lake. White Oak Creek joins the Clinch River at Clinch River mile (CRM) 22.8 at elevation 741 feet (McMaster, 1967).

Characteristic of the Ridge and Valley Province, most drainage of the area is of the trellis type. The master stream of the area is the Clinch River, an incised, meandering stream. The Clinch, along with the Powell, Holston, and Nolichucky-French Broad rivers form the headwaters of the Tennessee River (Thornbury, 1965).

Complete topographic map coverage of the state of Tennessee is available at a scale of 1:24,000 (7 1/2 minute quadrangles). The X-10 site and White Oak Creek drainage basin are located on the Bethel Valley, Tennessee quadrangle (1968). Adjacent land areas are found on the Lovell, Concord, Lenoir City, Cave Creek, Elverton, Petros, Windrock, and Clinton quadrangles.

2. Geology

(a) Areal Geology and Stratigraphy

The geology of the Oak Ridge area has been mapped and described previously. In 1950 a geologic map of the portion of Bethel Valley in the vicinity of ORNL was prepared by Klesper (see Stockdale, 1951). In 1954, Barnett mapped the southwestern portion of Melton Valley. A generalized soils map and summary mineralogical and chemical data from rock and soil samples collected in the Oak Ridge area was presented by Carroll (1961). W. M. McMaster of the U.S. Geological Survey mapped and investigated the geologic conditions of the Oak Ridge Reservation. This work, presented on a base map at a scale of 1:31,680 (2 inches = 1 mile), was published in 1963. Finally, McMaster and Waller (1965) reported on the geology and soils of White Oak Creek drainage basin. The geologic and pedologic information presented herein is summarized primarily from McMaster (1963), McMaster and Waller (1965), and Stockdale (1951).

For information on the regional geology of eastern Tennessee, the reader is referred to Hunt (1967), Miller (1974), Rogers (1953), and Wilson (1953, 1965, 1973).

The Oak Ridge Reservation is underlain by nine geologic formations or groups which range in age from Early or Middle Cambrian to Early Mississippian. All units are sedimentary in origin. From oldest to youngest, these geologic units and local outcrop areas are the Rome Formation (Haw Ridge area), Conasauga Group (Melton Valley area), Knox Group (Chestnut Ridge area), Chickamauga Group (Bethel Valley area beneath X-10), Sequatchie Formation, Rockwood Formation, Chattanooga Shale, Maury Formation, and the Fort Payne Chert. Of these the Rome, Conasauga, Knox, and Chickamauga units are much more important from the standpoint of occurrence and proximity to the X-10 site location.

Figure 3 depicts the geology and topography of White Oak Creek drainage basin. This area includes the ORNL site and immediate environs of principal interest. As seen in this figure, the sedimentary layers crop out along parallel belts trending northeast-southwest which conform with topography. Strike of the units averages north 56° east and dip is generally toward the southeast at angles commonly between 30 and 40 degrees. Local variations in attitude occur due to structural complexities. Total stratigraphic thickness in the area is approximately 9,000 feet.

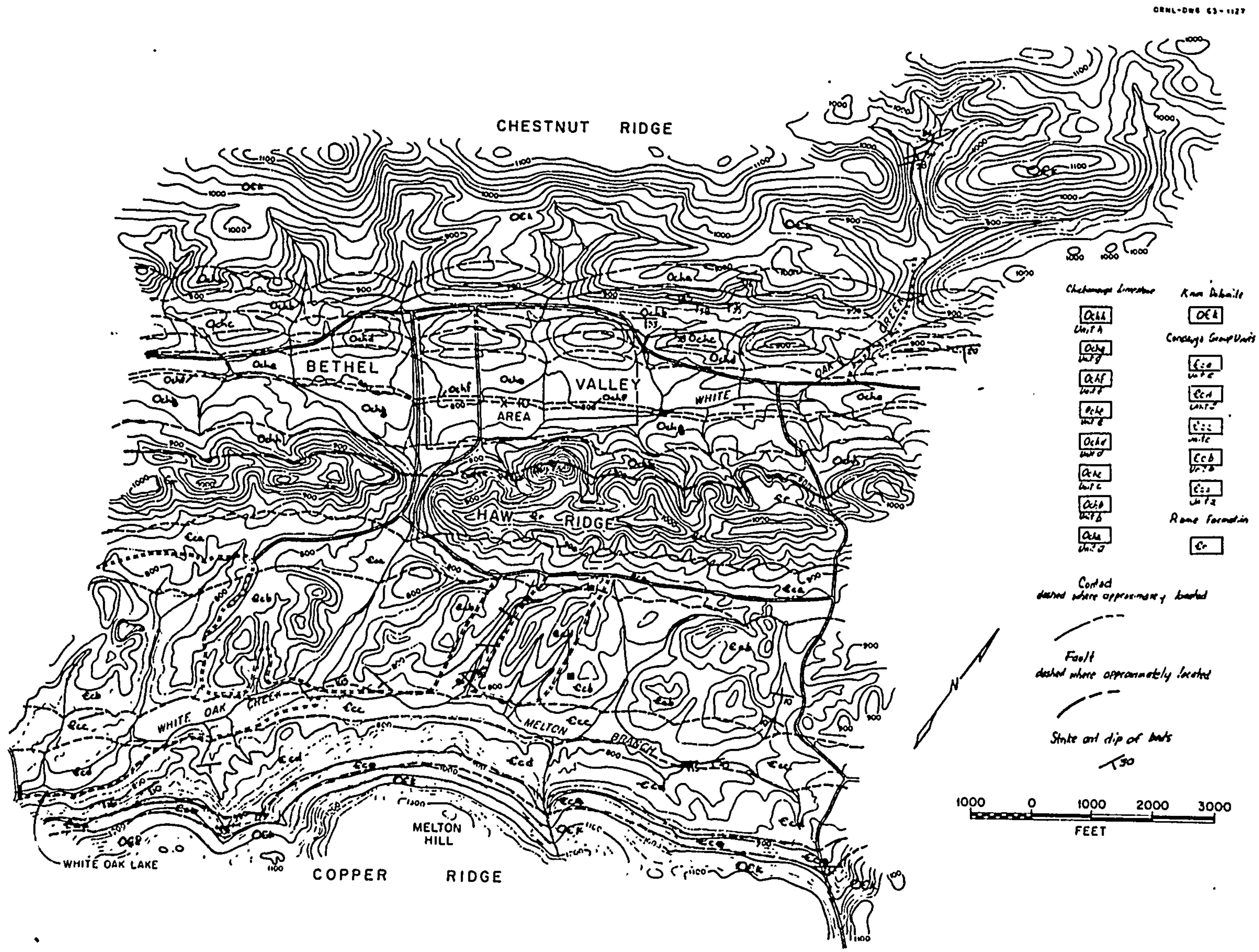

Fig. 3. Geologic map of White Oak Creek Basin (from McMaster and Waller, 1965).

The Rome Formation, of Early or Middle Cambrian age, underlies Haw Ridge, Pine Ridge, and the southeastern side of Gamble Valley. This formation is composed of interbedded sandstone, shale, siltstone, and locally, dolomite. Siltstone and shale predominate in the Oak Ridge area. The sandstone is composed of light gray to light brown, fine- to medium-grained quartz sand, cemented with iron oxide or silica. Siltstones tend to be brownish, thin-bedded, and with irregular bedding surfaces containing concentrations of mica.

The lower contact of the Rome is not exposed within the area, but it is consistently in a fault relationship with younger rocks beneath. The upper contact is gradational with the shales of the Conasauga Group. The total thickness is probably not present in the Oak Ridge area, but approximately 800 to 1,000 feet have been estimated locally. This formation forms ridges which are typically narrow, steep-sided, with many closely spaced wind and water gaps giving the ridges a "comby" appearance.

The Conasauga Group (Middle to Late Cambrian) is found in both Melton and Bear Creek Valleys. The group is composed primarily of calcareous and argillaceous shale interlayered with limestone and siltstone. The shale ranges from pure clay shale to silty shale of varying colors. Dense, nodular, thin-bedded, silty limestone is found interbedded with the shale and siltstone in the lower two-thirds of the unit. Alternating beds of dense to crystalline, regularly bedded limestone and shale are found about 500 feet below the top of the unit. These beds are overlain by approximately 300 feet of massive, dense to crystalline or oolitic limestone. Most of this upper unit is fairly pure calcium carbonate.

The total thickness of the Conasauga Group is difficult to measure because of many minor folds and faults, but it has been estimated to be 1,500 to 2,000 feet. The group underlies valleys between ridges upheld by the Rome Formation and Knox Group. The valley surfaces are generally irregular with gullies and small hills.

The Knox Group (Late Cambrian-Early Ordovician) is one of the most widely distributed stratigraphic units in east Tennessee. It is composed primarily of massive, silicious dolomite and can be divided into five formations. Some thin beds of limestone and sandstone are also present. The total thickness is about 3,000 feet. Because the amount of chert left by weathering is variable among formations, differing erosion rates produce an irregular, hilly topography. Underground solution channels are common and sink holes may be found on the land surface above the Knox. Springs are common at the Knox-Chickamauga contact.

The Chickamauga Group (Middle to Late Ordovician) is lithologically quite variable, but the entire sequence is calcareous. These strata are found in East Fork Valley, where a complete section is present (about 2,400 feet), and in Bethel Valley where the upper 500 feet or more have been faulted out. In East Fork Valley, the base of the group constitutes thin bentonitic layers, shale, and siltstone which are laterally discontinuous. Above these layers is a sequence of cherty, dense to finely crystalline, shaly, thin-bedded limestones up to 1,500 feet thick. Near the top of this sequence are two bentonite beds separated by about 50 feet of strata. Calcareous siltstones and coarsely crystalline, massive, fossiliferous limestone occur near the top of the sequence. The

Reedsville Shale (200-250 feet thick), a calcareous, fissile, thin-bedded, and fossiliferous unit, is the uppermost component of the Chickamauga Group. Lithologic units are more continuous and distinct in Bethel Valley and the group can be divided into at least eight units at this locality (Stockdale, 1951). No bentonites have been found in Bethel Valley. Sinkholes are present on the valley surface, but they are not abundant.

(b) Geologic Structure

Principal structural features of the Oak Ridge area are two major thrust faults with several subsidiary faults, a doubly plunging syncline, and strata which generally dip to the southeast. With few exceptions, dip angles range between 30° and 40° with an average of 36°. Strike averages 56° to 58° east of north.

The trace of the Copper Creek fault follows the northwestern slope of Haw Ridge. The Rome Formation is thrust over the Chickamauga Group with a stratigraphic throw estimated to be between 5,500 and 7,200 feet. The average strike of the fault is N 55° E and the dip is estimated to be 45° or more to the southeast. Associated small folds and faults in the upthrown Rome can be observed. White Oak Creek crosses the Copper Creek fault at Haw Gap. Results from core drilling reported by Stockdale (1951) indicate that the fault breccia and gouge are tightly cemented and thus impermeable.

The White Oak Mountain fault is a complexly branched thrust fault where Rome units have been thrust over Cambrian rocks. The structure originates near Clinton, Tennessee from the union of the Hunter Valley and Wallen Valley faults and subsequently trends southwest through the

State. Synclinal structures are characteristically found northwest of this fault. One such feature, the East Fork Ridge - Pilot Knob syncline, is doubly plunging with complexly faulted limbs. These latter features are located two to three miles northwest of the X-10 site (see McMaster, 1963).

(c) Surficial Geology and Soils

Owing to extensive weathering, a mantle of residual material nearly everywhere covers bedrock in the Oak Ridge area. In places this material is more than 100 feet thick. The physical characteristics of the regolith reflect the weathering characteristics and lithology of the underlying strata. Generally, the Chickamauga has the least thickness of residual material whereas the Knox has the largest.

Residual material from the Rome formation tends to be silty to sandy, coarse-textured with small amounts of micaceous clay. Fragments of siltstone and sandstone remnants are common and depth to unweathered bedrock is probably everywhere less than 20 feet.

McMaster and Waller (1965) describe residual materials derived from five distinct stratigraphic units within the Conasauga Group. Weathering has penetrated to about 20 feet where shale predominates but the weathered material retains the appearance of the parent rock. However, most of the calcium carbonate material has been removed. Residuum from the massive limestone tends toward a thin accumulation of orange-red granular clay containing little or no chert.

The Knox weathers to a light yellow-tan to red-brown largely kaolinitic clay held in place by abundant chert fragments and blocks. The bedrock surface beneath is very irregular and usually covered to a depth of 30 feet or more.

Residual material on the Chickamauga is typically heavy, yellow or yellow-brown montmorillonite-like clay containing small chips of chert, fragments of silstone, and small blocks of limestone. Overburden thickness usually ranges from 1 to 25 feet.

A soil-association map of White Oak Creek drainage basin is shown in Figure 4. Soils within the basin are largely members of the broad groups of red-yellow podsolic, reddish-brown lateritic and lithosols. In general, soils of the area are strongly leached, acidic, low in organic content, and have exchange capacities less than 10 milliequivalents per 100 grams of soil.

A wide range of physical and chemical properties are found in the soils around ORNL. Depth of the soil profile ranges from 6 inches in some shale and sandstone areas to over 15 feet in some dolomitic limestone and alluvial deposit areas. Surface texture is dominantly silt loam or cherty silt loam, but in eroded areas this may be silty clay. Subsoil texture varies from cherty silt loam to firm, plastic clay. Consequently internal soil drainage ranges considerably.

Soil pH ranges from near neutrality to strongly acid. Soils on Knox Dolomite contain kaolinite as the primary clay mineral and those derived from the Conasauga Shale contain predominantly illite and vermiculite. Chickamauga limestone soils contain a mixture of kaolinitic and illitic minerals with locally significant amounts of montmorillonitic clay minerals. Additional information on chemical and mineralogical properties of soils and rocks can be found in Carroll (1961) and soil profile descriptions of the units mapped in Figure 4 are given in Table 2 of McMaster and Waller (1965).

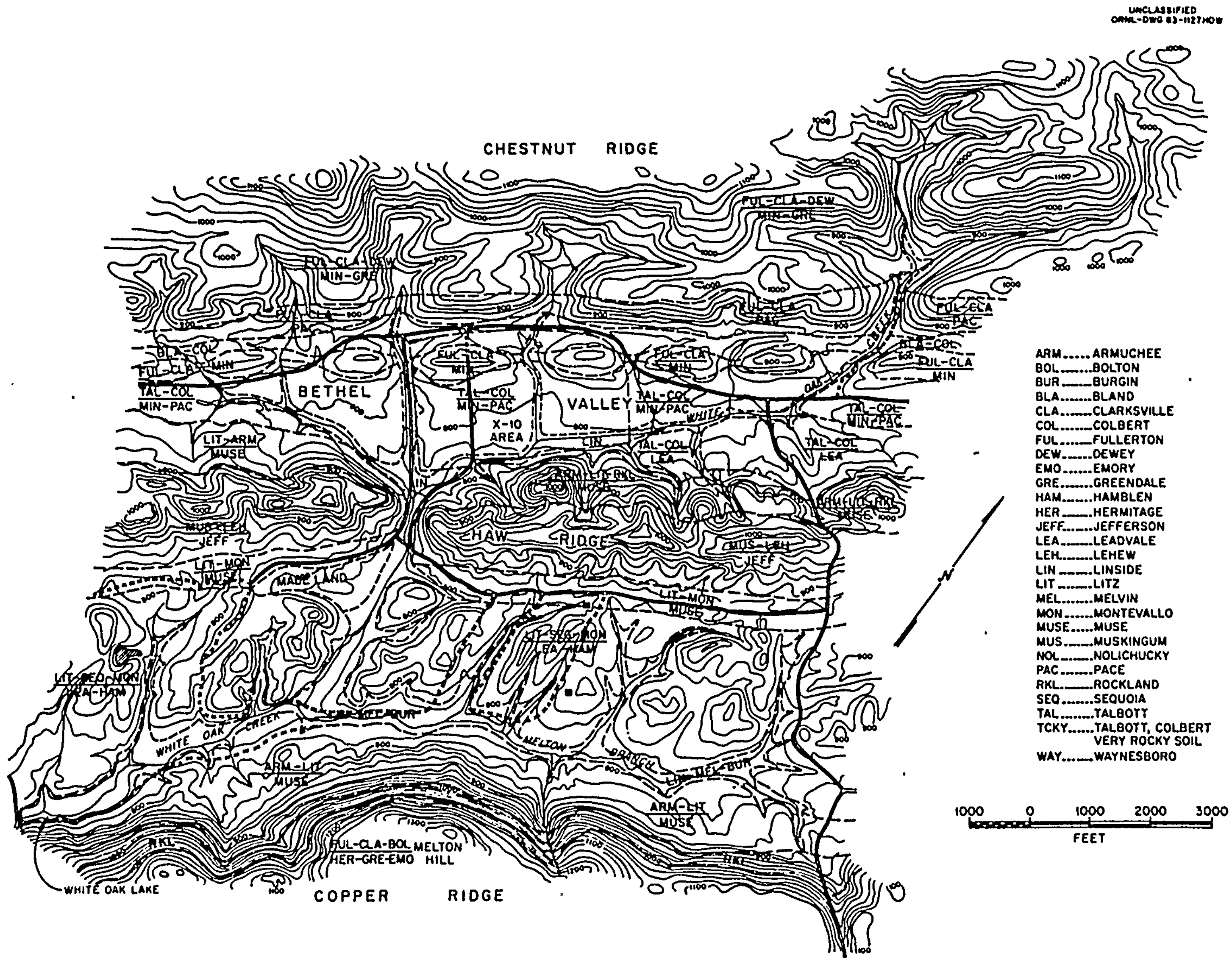

Fig. 4. Soil association map of White Oak Creek Basin. Common soils within each geologic belt, geologic unit, or topographic unit are listed according to relative abundance (most abundant to left) and toposequence (upland soils in numerator and colluvial-bench soils or bottom land soils in donominator) (from McMaster and Waller, 1965).

3. Climatology

The climate of the Oak Ridge area is typical of the humid southern Appalachian area and is significantly influenced by topography. Prevailing winds are usually up-valley, from a westerly or southwesterly direction, or down-valley, from an easterly or northeasterly direction (Fig. 5). Wind velocities are subdued by topographically high areas. Furthermore, winter climate is moderated by the retarding effect of the Cumberlands on cold air flow from the north and west (NOAA, 1975).

For the period of record from 1948 through 1975, average precipitation at Oak Ridge is 55.16 inches and mean temperature is 57.9°F. The coldest month is normally January (mean 38.4°F) with July being the hottest (mean 76.7°F). Temperatures greater than 100°F or less than 0°F are rare (see Fig. 6). The average daily temperature range is about 22°F with the greatest average range occurring in spring and fall with the smallest range in winter (NOAA, 1975).

Precipitation patterns exhibit seasonal variation. Winter and early spring is the time of heaviest precipitation with a secondary maximum in July due to thunderstorms. September and October are usually the dryest months. For the period of record at Oak Ridge, the mean monthly precipitation values, beginning with January, are as follows: 5.54, 5.19, 6.15, 4.27, 4.08, 4.15, 5.39, 3.68, 3.49, 2.90, 4.47, and 5.87 (NOAA, 1975). Figure 7 illustrates the average climatic conditions for the Oak Ridge area.

Owing to topographic influences and thundershower patterns, recorded precipitation can very significantly from one location to the next. For example, an isohyetal map of the Oak Ridge area (McMaster, 1967), based

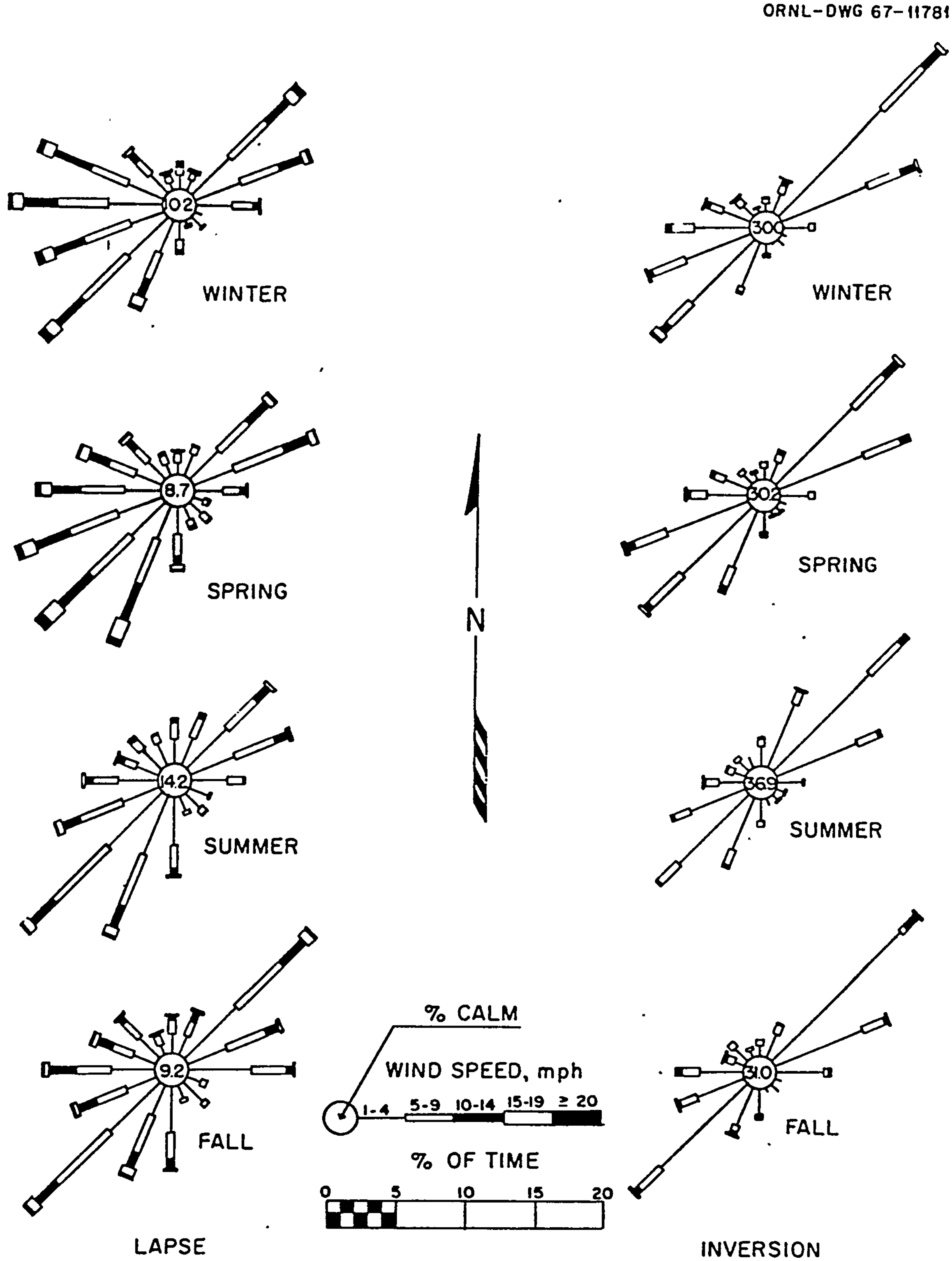

Fig. 5. Wind speed and direction during lapse and inversion (from Curlin and Nelson, 1968).

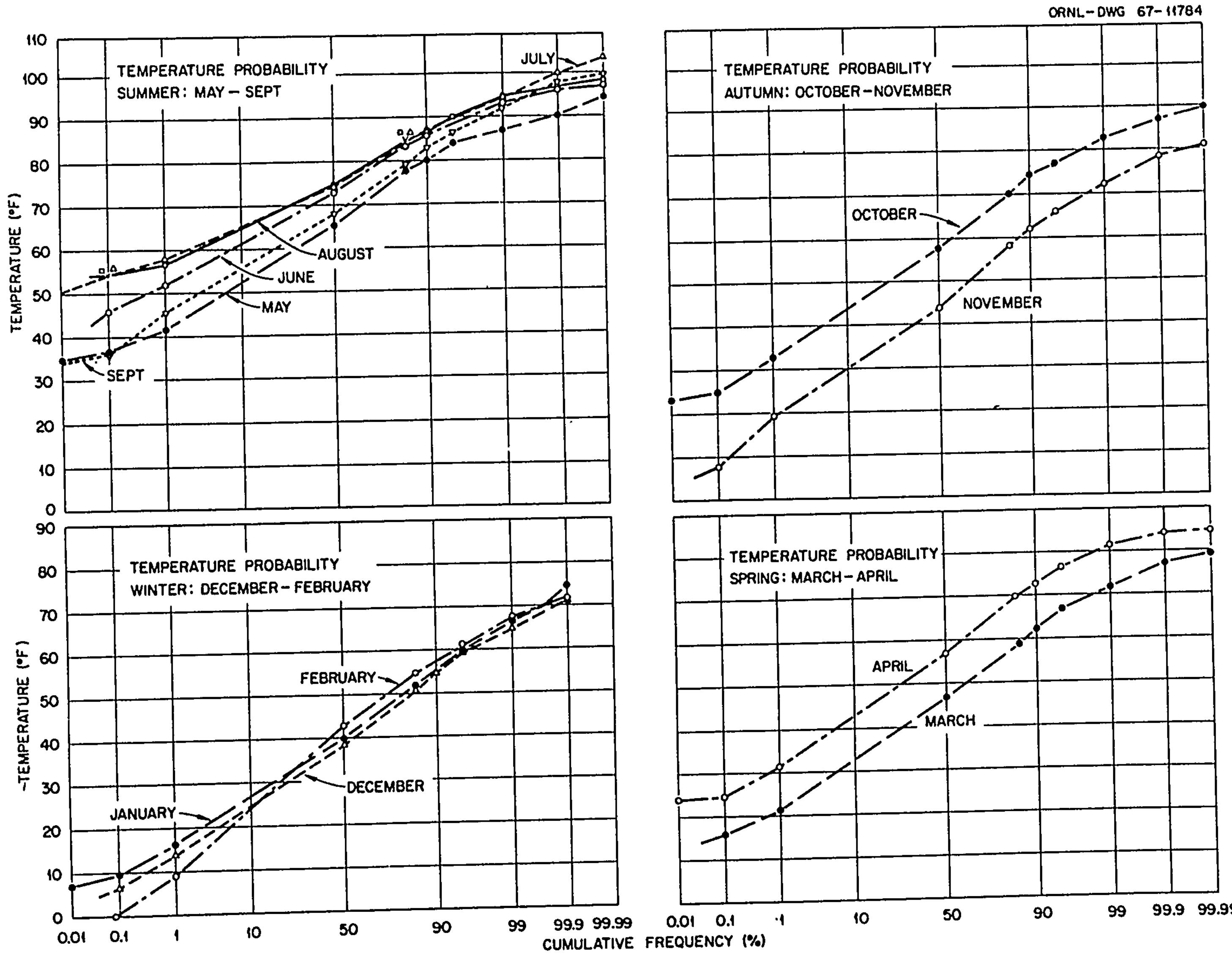

Fig. 6. Temperature probabilities by season (from Curlin and Nelson, 1968).

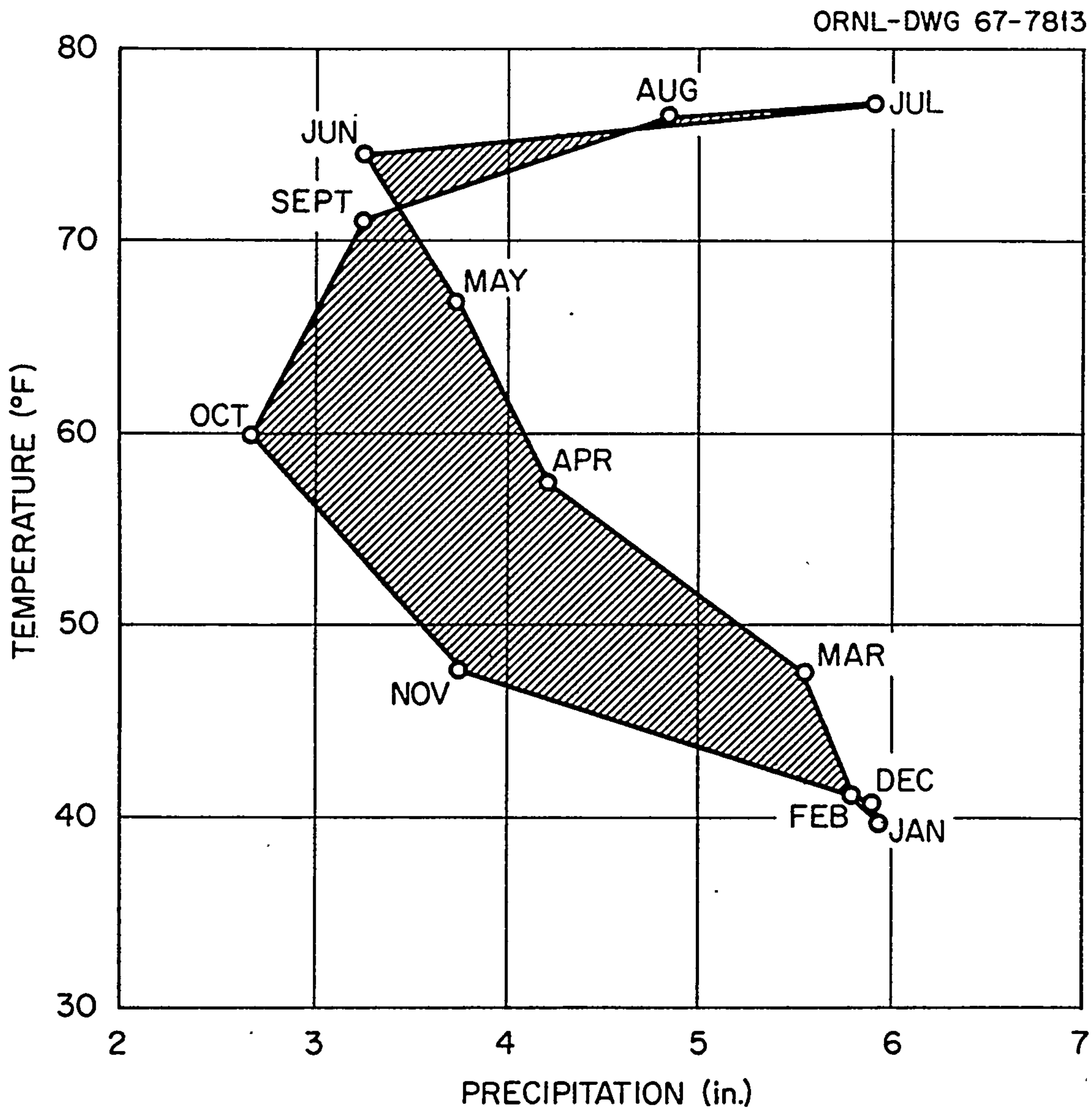

Fig. 7. Climatograph of the Oak Ridge area (from Curlin and Nelson, 1968).

upon data from 11 stations for water years 1936-1960, shows mean annual precipitation to vary from 46 inches to more than 59 inches in a distance of only 22 miles. McMaster (1967) reported the greatest rainstorm to occur at the town of Oak Ridge during the period of record 1936-60 was on the afternoon of August 10, 1960 when 7.43 inches of rain fell in 3.3 hours (see TVA, 1960). At the storm center, about 0.75 mile north of the gage, as much as 9 inches fell. McMaster reported that according to the U.S. Weather Bureau (1961), the recurrence interval for a rainfall of 3.4 inches/hour is over 100 years. Recurrence intervals for 1, 3, 24, and 48 hour duration rainfall for the Oak Ridge townsite are shown graphically in Figure 8. In terms of minimum precipitation, periods of five consecutive days without measurable precipitation occur about four or five times per year, 10 consecutive dry day periods average one or two per year and more than 11 days average less than once per year. A period of 31 consecutive days without measurable rainfall occurred in September and October, 1953 (NOAA, 1975). Occurrence of consecutive dry days is shown graphically in Figure 9.

Additional climatological data for the Oak Ridge area can be found in Oak Ridge Atmospheric Turbulence and Diffusion Laborabory (1972).

4. Hydrology

A drainage basin hydrologic cycle can be visualized as inputs of precipitation being distributed through a number of storages by transfer mechanisms, culminating in outputs via channel runoff, evapotranspiration, and outflow as ground water. Variations in annual runoff result from variations in rainfall and rates of water loss. Within the Oak Ridge area, greatest runoff occurs during the period of January through

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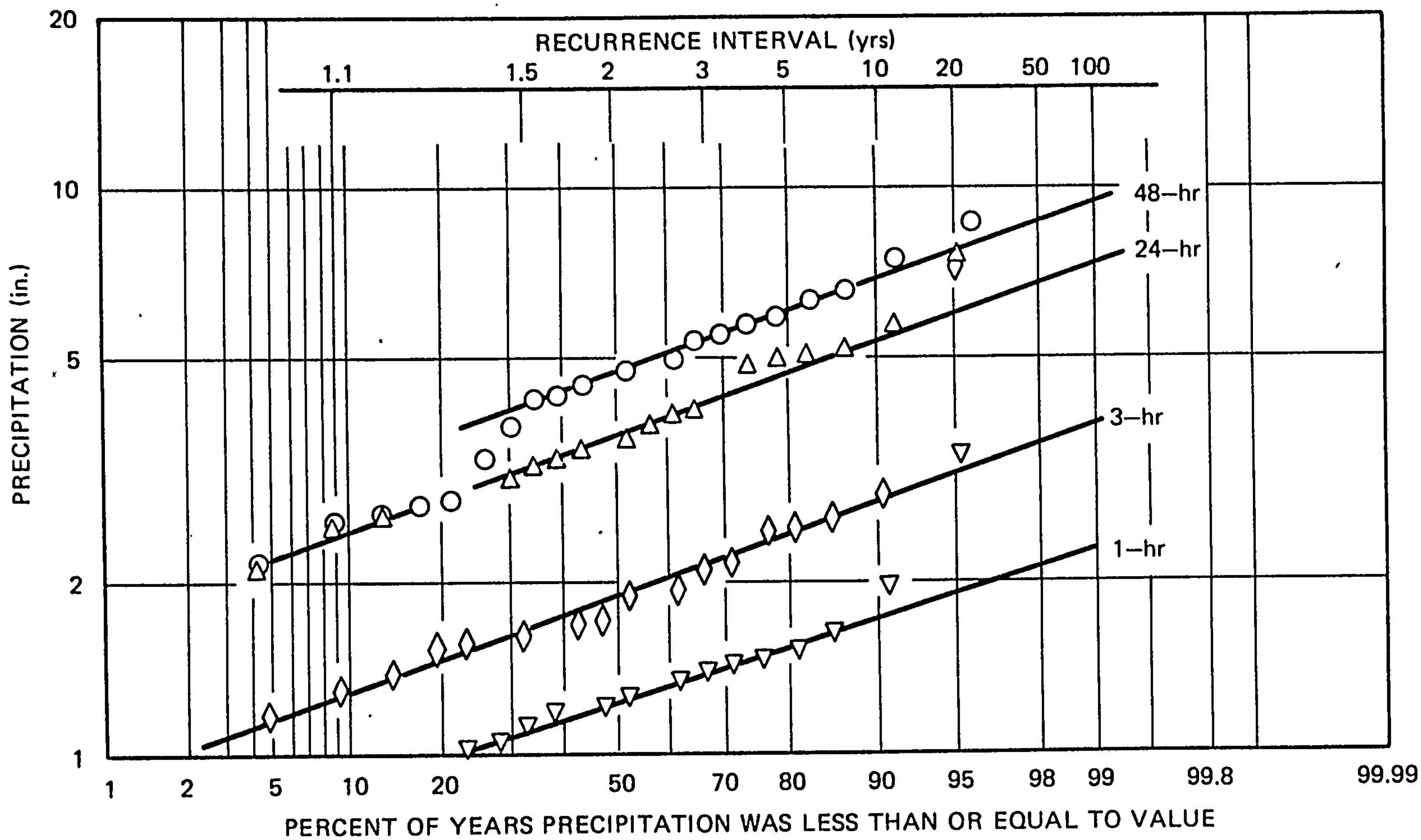

Fig. 8. Annual maximum series for precipitation at Oak Ridge for 1-, 3-, 24-, and 48-hr storms (Townsite Weather Station, 1951 to 1973) (from Sheppard, 1974).

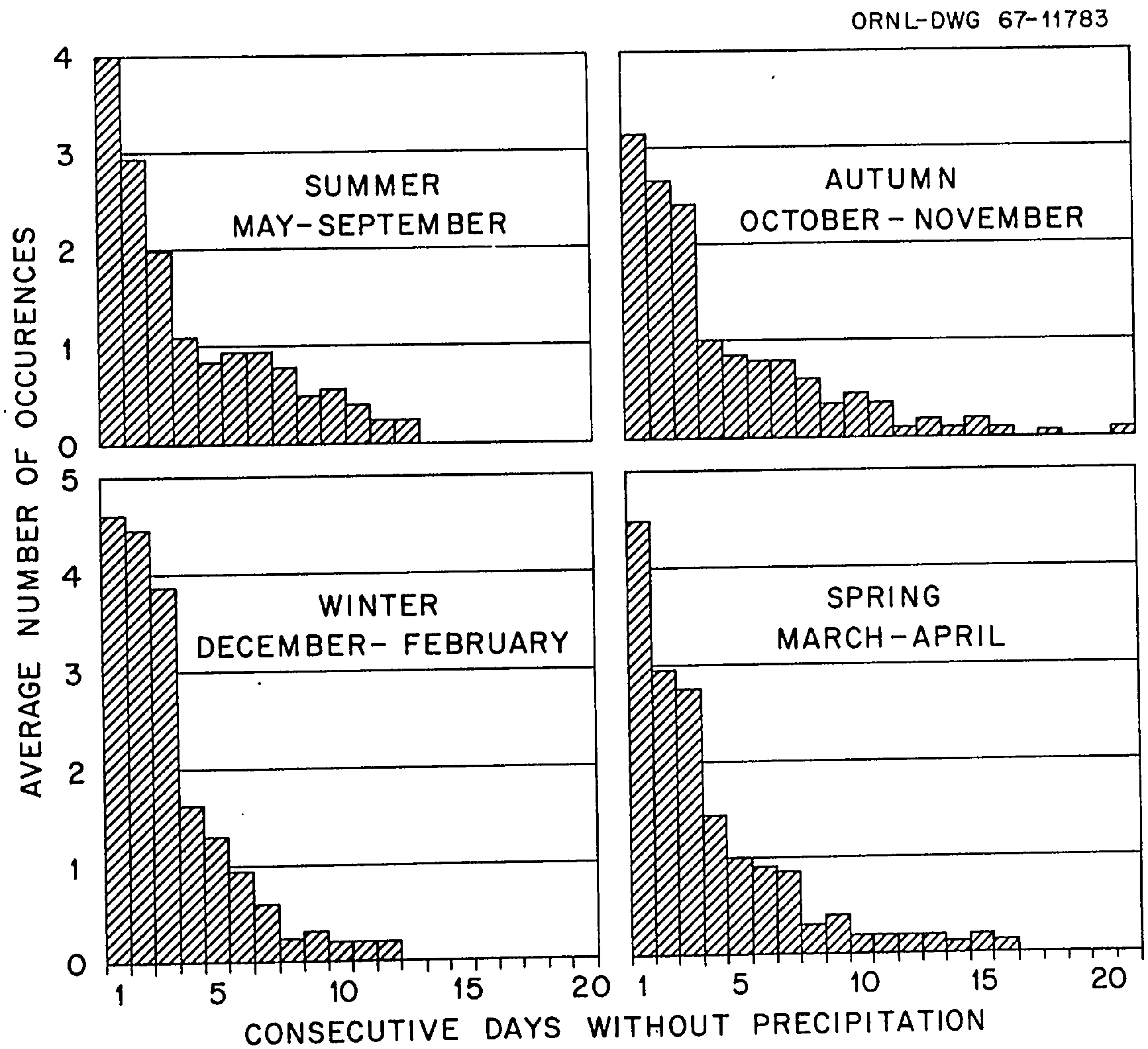

Fig. 9. Average occurrence of consecutive days without precipitation (from Curlin and Nelson, 1968).

March and the least during the quarter of July through September (Fig. 10). The average quarterly runoff from the area, as a percentage of annual runoff, is as follows: October-December (17%), January-March (49%), April-June (23%), and July-September (11%). McMaster (1967) reported a mean annual precipitation of 51.2 inches and an average annual runoff, exclusive of Clinch River, of approximately 22.3 inches. Based upon these data, on the average, runoff accounts for approximately 43.6 percent of precipitation. McMaster also noted that annual water loss by evaporation and transpiration was about 30 inches or about 55 percent of annual rainfall. Evaporation and transpiration losses are greatest during the July-September quarter when at least 80 percent of precipitation is lost.

Additional data and information on streamflow and storm runoff in the Oak Ridge area can be found in Ackerman (1949), McMaster (1967), Sheppard (1974), Speer and Gamble (1964), and Tennessee Valley Authority (1959).

Principal surface drainage of the ORNL (X-10) site is through White Oak Creek and its tributaries. The basin has a drainage area of approximately 6.5 square miles and the main channel has a length of approximately four miles. White Oak Creek originates on the forested slopes of Chestnut Ridge a short distance northeast of ORNL. Numerous springs provide a large portion of the discharge in this portion of the catchment.

Approximately 1.5 miles from the source, the creek enters ORNL and receives a significant discharge contribution in the form of waste water. Melton Branch drains about 1.5 square miles in Melton Valley and joins White Oak Creek about 1.5 miles above the junction with Clinch

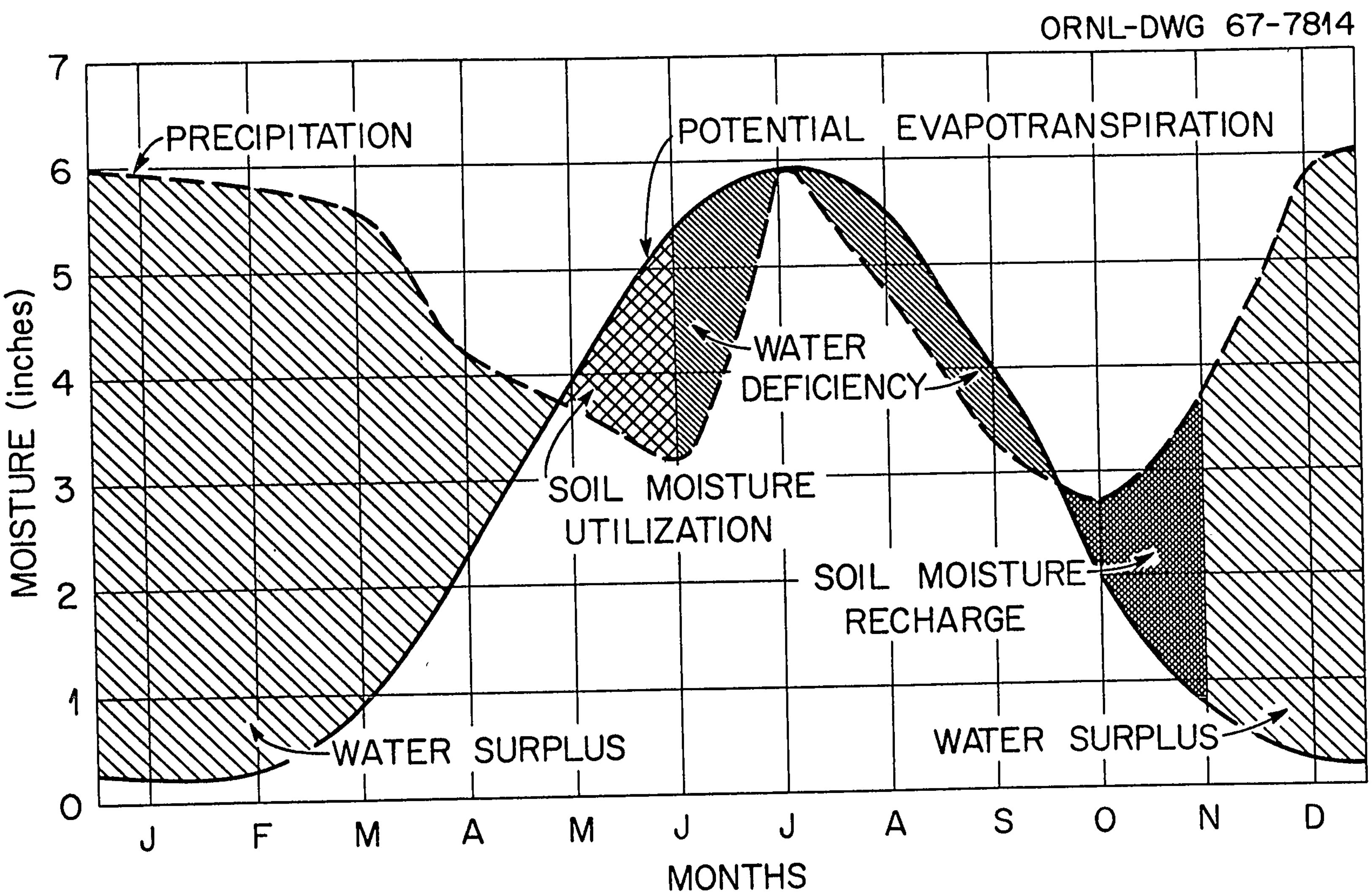

Fig. 10. Annual water balance of Oak Ridge area, assuming a soil moisture storage capacity of 12 inches (from Curlin and Nelson, 1968).

River (Fig. 11). Before entering the Clinch River, White Oak Creek flows into White Oak Lake, a 20-acre body of water impounded by an earthen dam constructed in 1946 43 (Dahlman and others, 1977). Below the dam, release water flows for approximately 0.6 miles to the Clinch River. The channel area below the dam resembles a large mud flat and is a site of active erosion-sedimentation activities depending upon water levels in the Clinch River resulting from release patterns at Melton Hill and Watts Bar Dams. During times of high stage on the Clinch, backwater extends up White Oak Creek to White Oak Dam and completely drowns out the normal channel.

Some discharge data are available for this watershed. Webster (1976) summarized data (U. S. Geological Survey, 1971) on White Oak Creek and Melton Branch at three sites. On White Oak Creek 0.1 mile above Melton Branch, the average, minimum, and maximum discharges for 10 years of record (1950-52, 1955-63) were 9.62 cfs, 1.9 cfs, and 642 cfs respectively. For Melton Branch 0.1 mile above White Oak Creek, the average, minimum and maximum values for the period 1955-63 were 2.50 cfs, 0 cfs, and 242 cfs. At White Oak Dam for the period 1953-55 and 1960-63, these values were 13.5 cfs, 0 cfs, and 669 cfs. Additional data, including daily flow duration values (Table 1) for Melton Branch and White Oak Creek, are given by McMaster (1967). About 90 percent of White Oak Creek dry-weather flow results from ground-water discharge and ORNL plant effluent.

In the Oak Ridge area the Knox Dolomite and the Chickamauga Limestone are the principal aquifers. The Rome Formation and Conasauga Group probably do not contain significant quantities of ground water.

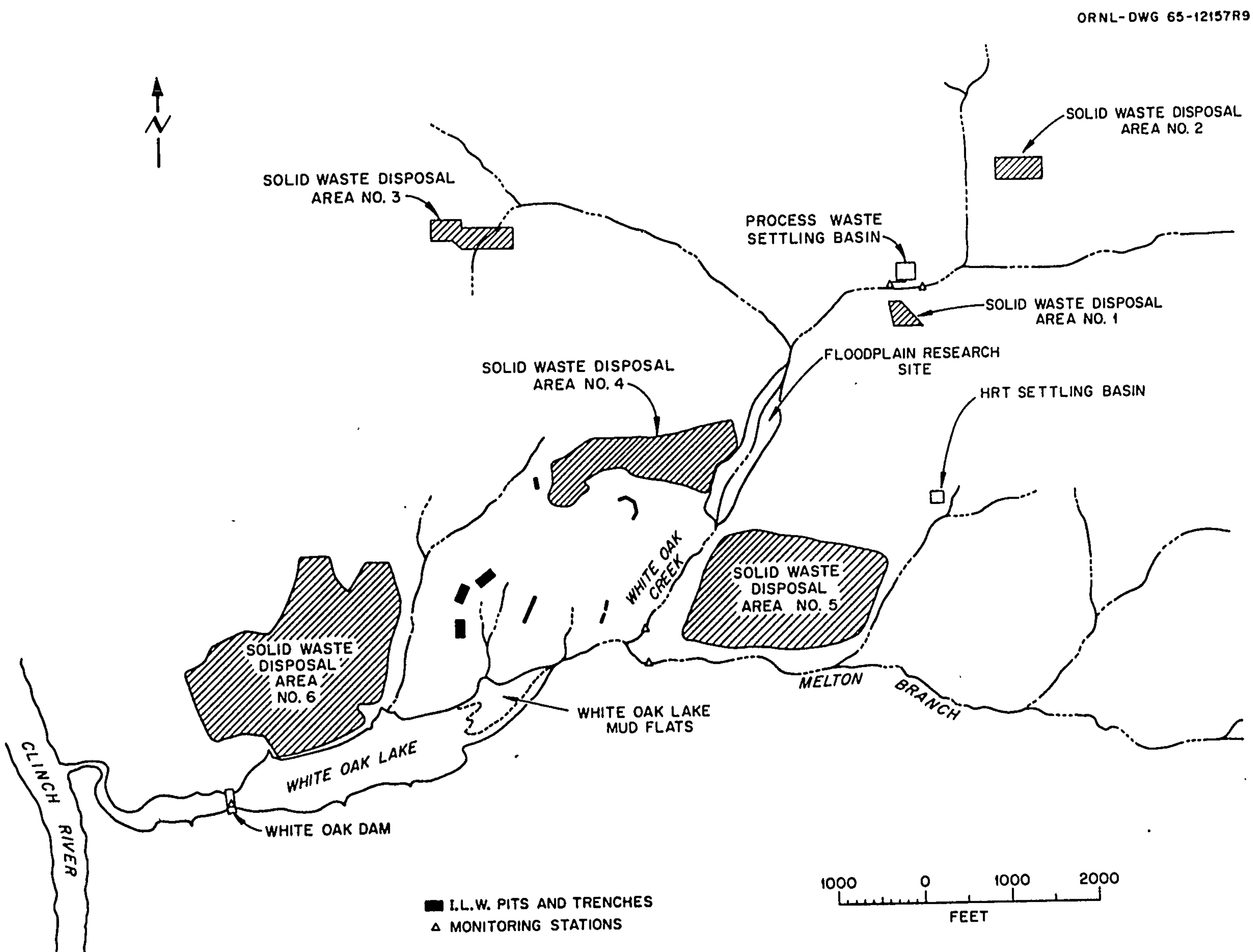

Fig. 11. Map of White Oak Creek drainage, monitoring station locations, and principal waste disposal areas for ORNL.

Table 1. Daily flow duration values (cfs) for White Oak Creek and Melton Branch. Data from Figures 11 and 12 of McMaster (1967).

	Percentage of time indicated discharge equalled or exceeded										
	99	90	80	70	60	50	40	30	20	10	1
Melton Branch	0.10	0.22	0.35	0.50	0.69	0.92	1.30	1.80	2.80	5.00	28.00
White Oak Creek at White Oak Dam	1.90	3.30	4.40	5.30	6.20	7.30	8.70	11.00	14.00	23.00	100.00

The Knox, located beneath Chestnut Ridge, is the major aquifer in White Oak Creek basin. The thick, weathered mantle seems to have a high infiltration capacity and serves as a reservoir feeding large solution cavities in the bedrock. Springs at the base of Chestnut Ridge are the primary natural source of base flow for White Oak Creek. Ground-water discharge from the Knox beneath Copper Ridge is probably not into White Oak Creek Basin but instead to the southeast along the Clinch River. Depth to the Knox water table in Chestnut Ridge is at a maximum of 125 feet at the ridge crest (McMaster and Waller, 1965).

Most openings in the Chickamauga are only a few inches in diameter because of the limestone's more thinly bedded, shaly characteristics. Additionally, the weathered mantle is primarily heavy clay less than 10 feet thick; consequently, infiltration and recharge are limited. Undoubtedly, rates and quantities of water movement are relatively small even though a significant quantity of ground water may be stored in the unit near the surface (McMaster and Waller, 1965).

In the siltstones and shales of the Rome Formation and Conasauga Group, water is found only in small openings or partings along joints and bedding planes. Because these rocks contain little calcium carbonate and thus are relatively insoluble, these openings have not been enlarged significantly (McMaster, 1967).

A detailed review and examination of ground-water and geologic conditions at ORNL and their relation to radioactive waste disposal was recently published by Webster (1976). Local ground-water conditions at several locations in White Oak Creek watershed are presented in Webster's report.

Depth to the water table varies both spatially and temporally. At a given location, depth to water is generally greatest during the October-December quarter and least during the quarter January through March (see McMaster, 1967, Fig. 7). In Bethel Valley depth to water table ranges from 1 foot to 35 feet whereas in Melton Valley the range is from 1 foot to 67 feet (Webster, 1976). Seasonal fluctuations tend to be greatest beneath hillsides and near the ground-water divide. As much as 15 feet seasonal variation was reported by Webster (1976) for Melton Valley. A generalized map showing the range in depth to ground water in White Oak Creek Watershed during March, 1963 is given in Figure 12.

Water-table contour maps are useful, in a general way, for estimating the direction of ground-water movement, especially in the weathered residuum or unconsolidated materials overlying bedrock. However, direction of movement in the underlying strata is influenced more strongly by directional variations in permeability. Ground-water flow in the residuum is generally toward the individual channels of the surface-drainage network. In Bethel Valley, ground water in the Chickamauga Limestone moves through small solution channels. Direction of movement is complex and controlled by the three-directional geometry and degree of interconnection of the solution openings. There is no reported evidence indicating subsurface movement from the X-10 area of Bethel Valley to adjacent drainage basins (Webster, 1976).

Ground-water movement in the Conasauga of Melton Valley has been considered in four separate investigations and reviewed by Webster (1975) (see Morton and others, 1954; Struxness, 1955; Cowser and Parker,

Fig. 12. Map illustrating general depth to ground water in White Oak Creek Basin during March 1963 (from Lomenick and others, 1963).

1958; De Laguna, Cowser, and Parker, 1958; Lomenick, Gera, and Wyrick, 1964; Lomenick, Jacobs, and Struxness, 1967). Each investigation concluded that within the study area, the primary direction of ground-water movement in the Conasauga is parallel to strike. This observation suggests that greatest permeability in unweathered bedrock is associated with partings between beds and perhaps with residue of more soluble units. However, Webster (1976) reported that factors controlling fluid movement within the Conasauga vary with depth. He concluded that in the uppermost portion of the saturated zone, the slope of the water table (hydraulic gradient) is the primary factor controlling movement. With increasing depth, there is a change in control from the areal hydraulic gradient to control by local hydraulic head distribution within the partings, joints, fractures, or other more permeable zones within the rock. Webster (1976) also reported that the rate of movement in limestone beneath Bethel Valley is relatively slow because of the small size of solution cavities observed in drill cores and the slow recovery of wells after pumping (see De Buchananne, in Stockdale, 1951). The best current estimate of movement rate in the Conasauga under natural conditions is about 0.56 feet/day along strike for the first 5 feet and only slightly less than this out to a distance of 10 feet (Lomenick, Jacobs, and Struxness, 1967).

5. Ecology

The Oak Ridge Reservation is typical of the ecological systems which occur in the Appalachian Region of the eastern United States. A preliminary inventory of the vegetation of the Oak Ridge area was compiled by Olson and others (1966). This listing has subsequently been supplemented with observations of spring flowering of 171 species of herbaceous and woody plants from 55 different families (Taylor, 1969).

Seven vegetation types have been identified on the Oak Ridge Reservation (USERDA, 1975).

1) Yellow Pine/Yellow Pine-Hardwoods. This is presently the most extensive type on the reservation. These areas are dominated by shortleaf and Virginia pine in association with large tracts of planted loblolly pine. Associated species in the natural succession forests include oaks, hickories, and tulip poplar.

2) Hemlock and/or White Pine/Hemlock and/or White Pine with Hardwoods. This type represents a Southern Appalachian extension of a northern, higher elevation forest and is extremely restricted in occurrence. Hemlock and white pine dominate.

3) Cedar and Cedar Pine/Cedar-Hardwoods. An extensive type predominating in Bethel Valley and areas close to the Clinch River. The dominant species is eastern red cedar associated with shortleaf and Virginia pine, tulip poplar, oaks, hickories, redbud, sassafras, and other hardwoods.

4) Bottomland Hardwoods. This vegetation type is restricted to floodplain-creek bottom areas. Dominant species include cottonwood, sycamore, elm, ash, willow, silver maple, and river birch.

5) Upland Hardwoods. This type occurs over approximately 20 percent of the reservation area. This forest is essentially an oak-hickory complex representing the terminal type in this geographic region. Important species include chestnut oak, white oak, black oak, northern red oak, scarlet oak, post oak, various hickories and ash, tulip poplar, red maple, black gum, dogwood, beech, and others.

6) Northern Hardwoods. This forest type is very rare on the reservation, occurring only in restricted areas on Black Oak and Copper ridges. Composition is similar to the Upland Hardwood type with sugar maple, hemlock, basswood, and buckeye also being present.

7) Nonforest. This category includes primarily grasslands, devegetated areas, and cultural features. Native or semi-native areas include species of bluestem, fescue, and bluegrass.

Three distinct terrestrial animal habitats have been identified on the Oak Ridge Reservation (USERDA, 1975; Dahlman and others, 1977).

1) Hardwood-Mixed Hardwood Habitat. Sporadic sampling of small-mammal populations indicates that six species are common in this oak-hickory, chestnut oak, pine forest type. These are white-footed mouse, eastern chipmunk, golden mouse, short-tailed shrew, flying squirrel, and house mouse. Both red and gray fox are common predators. Opossum, raccoon, striped skunk, and bobcat inhabit varied areas and roam through upland forest areas. White-tail deer are also found in upland and bottomland forests, and a large number of bird species are also present in this particular habitat.

2) Pine Plantation Habitat. Animal populations of these pine communities have not been sampled extensively. It seems only three small-mammal species use these areas extensively (white-footed mouse, golden mouse, and short-tail shrew). Pine mouse, cotton rat, and harvest mouse were also observed. Large mammals, gray squirrels, opossum, deer, and predators probably use this habitat for shelter. Pine warbler and white-throated sparrow appear to be very common but few other birds were surveyed.

3) Old-Field and Grassland Habitat. Cotton rats, white-footed mice, golden mice, rice rats, short-tailed shrews, and eastern harvest mice have been trapped in this habitat. Some game birds, such as quail, and raptorial species use these areas as do sparrows, towhees, blue grosbeaks and other field species of birds.

The herpetofauna of the area have been described and habitat types categorized (Johnson, 1964). Various species of salamanders, turtles, frogs, toads, lizards, and snakes have been identified.

The Clinch River provides an aquatic habitat typical of the area. Submergent plants include Potamogeton, Chara, Najas, Elodea, and Myriophyllum (Milfoil). Phytoplankton samples indicate diatoms, dinoflagellates, blue-green algae, euglenoids, and green algae are present. Communities of zooplankton, composed primarily of Rotifera species, exist in slow water areas of Melton Hill Reservoir and backwater areas of the Clinch and tributary streams. Samples of benthic macroinvertebrates indicate the presence of Corbicula clams, the oligochaete Najas, Chironomidae, annelids, arthropods (insects and crustaceans), and coelenterates. Hydra is the dominant organism. Predominant fish species in the Clinch River adjacent to the reservation are gizzard shad, threadfin shad, skip-jack herring, carp, smallmouth buffalo, white bass, white crappie, sauger, and freshwater drum (USERDA, 1975).

It should be noted that fisheries resources of the Tennessee River system are utilized by both sport and commercial fishing activities. Some commercially harvested species (for example carp and buffalo) are sold for human consumption. Records of commercial harvests from the Tennessee River for the period 1946-1963 range from a low yield of

1,073,000 pounds in 1947 to a high of 8,532,000 pounds in 1963. These takes were comprised mainly of catfish and buffalo (Clinch River Study Steering Committee, 1967).

White Oak Lake has been described as having high phytoplankton productivity and a well developed benthic fauna, with various insect larvae being the most common forms (Kolehmainen and Nelson, 1969). Fishes present in the shallow embayment include bluegill and redear sunfish, largemouth bass, warmouth, gizzard shad, golden shiners, goldfish, and mosquitofish (USAEC, 1974).

A listing of typical habitat types of 212 animal and bird species of the Oak Ridge Reservation can be found in USERDA (1975), and Dahlman and others (1977) have tabulated an extensive list of species found in different aquatic habitats on the Reservation. Additional information regarding the ecology, flora, and fauna of the Oak Ridge area may be found in Anderson and Shugart (1974), Howell (1958), Howell and Dunaway (1959), Kitchings and Mann (1976), Krumholtz (1954a, 1954b, 1954c), and Mann and Bierner (1975).

6. Natural Phenomena

Certain naturally occurring events, usually of large magnitude and low frequency of occurrence, present significant environmental hazard. These destructive forces are important elements of site characteristics. The most significant natural phenomena in this regard are flooding, tornadoes, and earthquakes.

(a) Floods

Sheppard (1974) reported on storm runoff and flooding in the vicinity of Oak Ridge as well as reviewing previous investigations. From the record of storm events throughout the Tennessee Valley, Ackerman (1949) estimated that discharges as large as 16,000 cubic feet per second (cfs) or 2,450 cubic feet per square mile (cfsm) could occur on White Oak Creek. Based upon predicted maximum possible precipitation of 30 inches in six hours, Ackerman further estimated that maximum possible discharge on White Oak Creek would be 18,000 cfs or 2,830 cfsm.

From an investigation of flood magnitude and frequency in the Cumberland and Tennessee River basins, Speer and Gamble (1964) reported that for the hydrologic area including Oak Ridge, stream discharge as high as 13,000 cfs can occur on watersheds as small as 1.5 square miles (approximately 9,000 cfsm). Sheppard (1974) analyzed peak storm flow in the Oak Ridge area during storms which occurred on December 31, 1969, March 16, 1973, and November 28, 1973. His analysis indicated a relationship between maximum observed discharge and drainage area described by the equation

$$Q = 15,000\ A^{0.004}.$$

Incorporating the effect of precipitation, Sheppard (1974) found that for total storm precipitation (P) in the range of about 3 to 10 inches, the relationship

$$Q = 4.7\ A^{0.8}\ P^{2}$$

could be used to estimate maximum discharge given drainage area and precipitation. For further information on flood discharges in the Oak Ridge area and the limits of application for the above equations, the reader is referred to Sheppard (1974).

(b) Tornadoes

A study of tornado occurrences in Tennessee by Vaiksnoras (1971) indicates that the incidence of this type of storm in the Oak Ridge area is quite rare. This is primarily due to the presence of the Cumberland Mountains to the west and the broken terrain in the vicinity. However, numerous tornadoes have been reported in the broad valleys southwest and northeast of the area (Fig. 13). A total of 49 individual tornadoes with track lengths of 15 miles or larger occurred in Tennessee from 1916 to 1970 (Viaksnoras, 1971). As Figure 13 indicates, most of these were confined to the central and western portions of the state. Based on a relationship developed by the U.S. Weather Bureau (Thom, 1963), the expectation that a tornado would strike a given point in the vicinity of ORNL is approximately once in 2,500 years.

On May 2, 1953, at approximately 3:30 a.m., a small tornado passed through the Oak Ridge Reservation. However, this is the only recorded case of such a storm on the reservation since it was established and no damage was sustained (Binford and Gissel, 1975).

(c) Earthquakes

Algermissen (1969) prepared a seismic risk map of the United States based upon an evaluation of the known intensities and distribution of earthquakes, strain release data since 1900, and the association of strain release patterns with large-scale geologic features believed to be related to seismic activity. This map (Fig. 14) shows that east Tennessee is located in Zone 2. Within such areas, moderate earthquake damage could be expected that would correspond to an intensity of VII on the Modified Mercalli Intensity Scale of 1931 (Wood and Neumann, 1931). This intensity corresponds to a Richter magnitude of 5.2-5.7. The

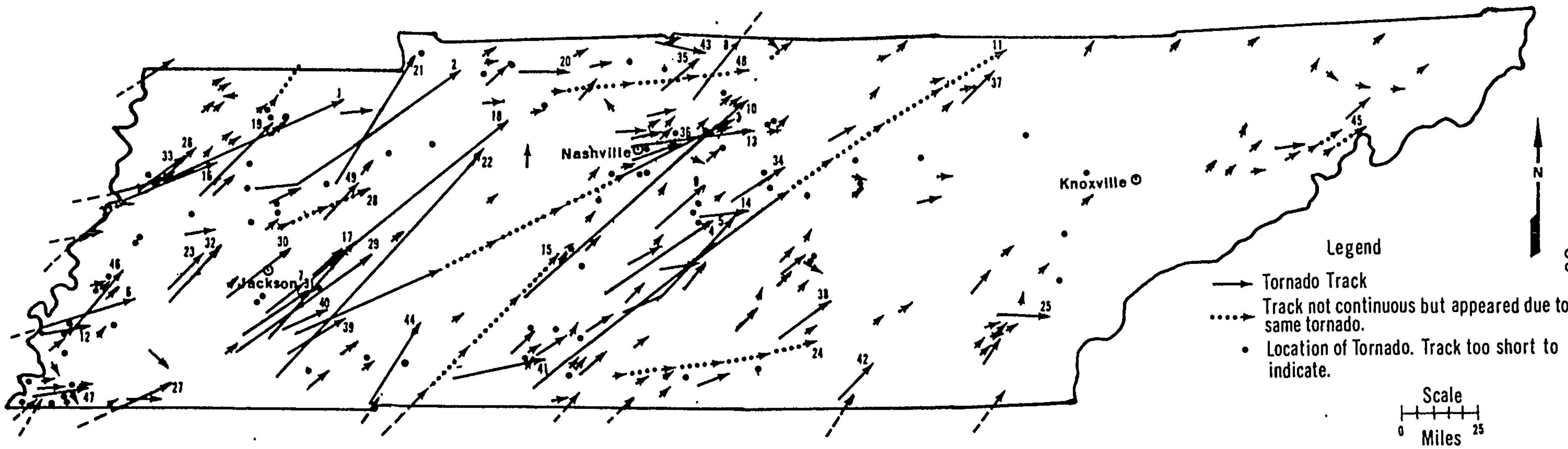

Fig. 13. Tracks of all tornadoes in Tennessee for the period 1916-1970 (from Vaiksnoras, 1971).

ORNL-DWG 70-4217

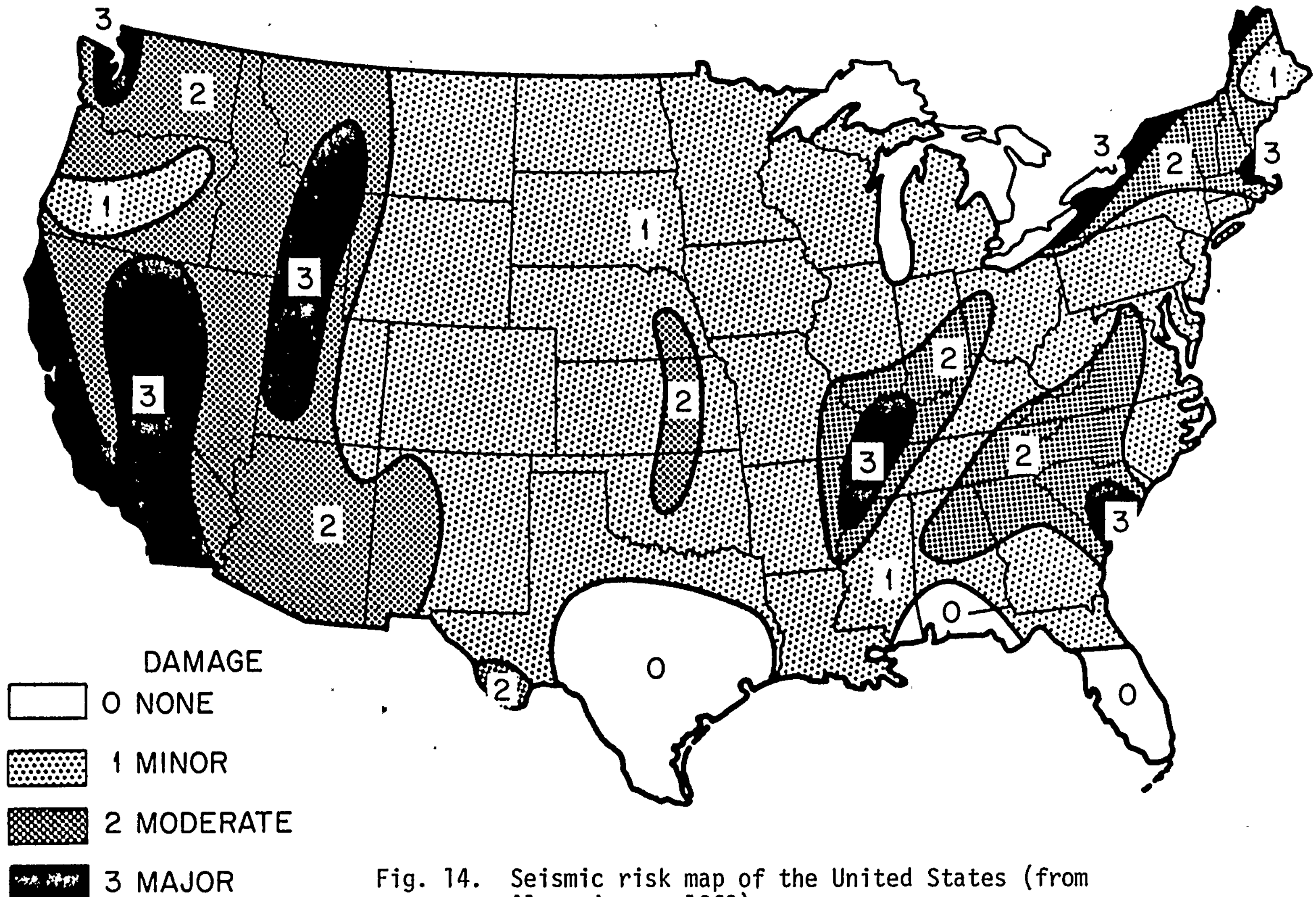

Fig. 14. Seismic risk map of the United States (from Algermissen, 1969).

effects of a VII intensity shock are: "Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars" (Wood and Neumann, 1931).

McClain and Myers (1970) compiled the seismic history of the southeastern region of the United States. This history incorporates 695 individual seismic events with 597 of these having epicenters within the defined southeastern region (Fig. 15). The correspondence between the distribution of epicenters (Fig. 15) and seismic risk zonal boundaries (Fig. 14) is readily apparent.

Kellberg (1973) reported that for the 100-year period of 1872 to 1971, 109 earthquakes have had epicenters within a 100-mile radius of Knoxville, Tennessee. In relation to the Modified Mercalli Intensity, 20, 28, 26, 21, 12, and 2 events were of intensity II, III, IV, V, VI, and VII respectively. Kellberg (1973) also calculated the probability of a quake of any given intensity that might occur annually in the 7,850-square mile area surrounding Knoxville. His results indicate that the percent probability of an earthquake of intensity II, III, IV, V, VI, and VII occurring in any one year is 20%, 28%, 26%, 21%, 12%, and 2% (Kellberg, 1973, Fig. 3).

The immediate vicinity of Oak Ridge experienced an earthquake on November 30, 1973. This shock had an intensity of IV-V and the epicenter was about 30 miles southeast of the ORNL site. There was no observed damage from this quake which had an estimated intensity of V at the X-10 site (Binford and Gissel, 1975).

ORNL-DWG 70-4221

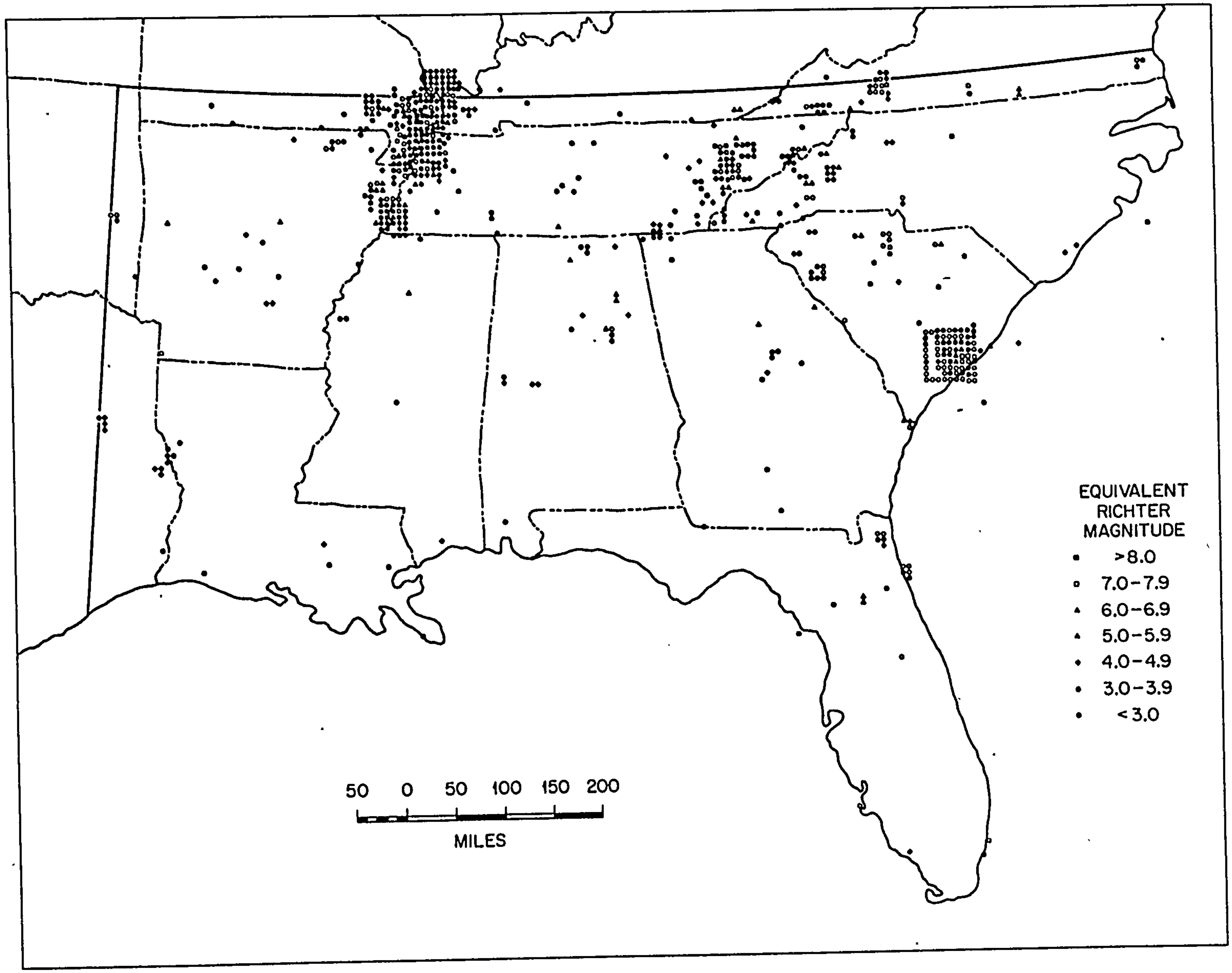

Fig. 15. Epicenter locations for all events in the seismic history of the southeastern region of the United States (from McClain and Myers, 1970).

Earthquakes are associated with crustal faulting. The faults in the Oak Ridge area are old, geologically speaking (several hundreds of millions of years), and show no evidence of recent movement. In the subsurface, faults intersected by drilling operations are filled with finely crushed rock and are quite impermeable to water flow. The absence of secondary alteration or mineral deposition indicates that only minor amounts of water, if any, have ever moved through the fault zone.

7. Natural Resources

Very little information is readily available with which to assess the natural resources of the Oak Ridge Reservation and the immediately surrounding area. The Oak Ridge area is located within the Tennessee Valley and, as a consequence, water is abundant and an important natural resource. The system of reservoirs on the Tennessee River and its principal tributaries are multi-purpose and many are in close proximity to the ERDA facilities. Aside from providing water for domestic and industrial use, these reservoirs provide recreational facilities for the local population. Fishing, boating, swimming, and other forms of water and outdoor recreation activities are available. In addition, many dams are used for electric power generation. Melton Hill Reservoir is located along the southern and eastern boundary of the Reservation and Norris Dam is only a few miles upstream on the Clinch River.

Agricultural productivity of the soils in the area is quite variable. The potential for productivity is based upon the physical and chemical characteristics of the soil and on conservation and topographic features of the landscape. Usually soils are ranked into five classes with first-class soils being the most productive (see Swann and others, 1942). These soil classes provide a basis for summarizing land-use potential for agriculture as follows:

Type 1 - Land is favorably productive, workable, and has minimal conservation problems. This type includes first-, second-, and third-class soils. Approximately 15% of the land on the Oak Ridge Reservation falls within this category.

Type 2 - Land characterized by moderate productivity but unfavorable workability. Frequent conservation problems are encountered; fourth-class soils make up this land type. Approximately 35% of the reservation is included in this category.

Type 3 - Fifth-class soils, suitable only for forestry, comprise this land type. Approximately 50% of the reservation falls in this group (USERDA, 1975; Dahlman and others, 1977).

The potential exists for some mineral resources in Anderson and Roane counties. This is largely determined by local geologic conditions, especially the lithologic and chemical characteristics of stratigraphic units. Carbonate rocks (limestone and dolomite) can be economically important as sources of crushed stone, agricultural limestone, lime, cement, and dimension stone. Some shales can also be used for brick and lightweight aggregate manufacture, and certain sandstones can be quarried for dimension stone. The suitability of local bedrock for industrial usage depends not only upon physical and chemical rock characteristics, but also upon surrogate sources in the surrounding area, ease of extraction, external supply, and many other economic considerations. Rock quarries are present in the Oak Ridge area and large quantities of coal are mined in the Cumberland Mountains area to the west. Additional, detailed information on the mineral resources of the Reservation and its environs is lacking. However, one could conjecture that they are relatively minor in occurrence and economic contribution.

Maher (1973) summarized the mineral resources of Knox County and reported 23.9 million dollars of mineral production for the county in 1970. Even though geologic conditions are similar between Knox, Anderson, and Roane counties, mineral resource comparisons would be very difficult because of local geologic, physiographic, economic, industrial, and demographic variations. Additional information on the mineral resources of the Oak Ridge area may be present in publications by the U. S. Bureau of Mines and the Tennessee Division of Geology.

8. Cultural Features, Demography, and Land Use

The 92-square-mile Oak Ridge Reservation was originally purchased for nuclear production and research with surrounding security and safety buffer areas. Originally 59,000 acres were acquired in 1942, but the area has been reduced subsequently to approximately 37,000 acres (about 58 square miles) through land transfers to municipal government and to state and Federal agencies (see Curlin, 1965). The populated area of Oak Ridge begins approximately 5 miles north of the X-10 site and the city limit of Knoxville, the largest city in the area, is approximately 13 miles east of the plant site. Oak Ridge population was approximately 28,000 in 1970 whereas that of Knoxville was approximately 175,000. There are 21 urban centers of 1970 population over 2,500 and 27 centers with population less than 2,500 within a 50-mile radius of the X-10 site (CRBRP-ER). Other 1970 census data indicate a total population of 678,800 within a 50-mile radius which yields a population density of 33 people/square mile. The projected population for this same area for the year 2000 is 899,281 and a population density of 44 people/square mile (CRBRP-ER). The total population within a 70-mile radius is reported to have been 1,025,864 in 1970 (U. S. Atomic Energy Commission, 1974).

Several historical features are found on or near the Oak Ridge Reservation. The "National Register of Historic Places" lists the ORNL Graphite Reactor in Oak Ridge, the Roane County Court House in Kingston, Southwest Point in Kingston, Harriman City Hall in Harriman, and the Lenoir Cotton Mill in Lenoir City (CRBRP-ER). All of these are within about 15 miles or less of the X-10 site. Furthermore, several structures of historical interest, but of questionable significance, are found on the reservation itself and surrounding area. These include cemeteries and various types of farmstead structures in varying states of demise and representing varying dates of construction. It is doubtful that any of these sites merit preservation because of their historical significance.

Fielder (1974) conducted an archaeological survey of the Oak Ridge Reservation with emphasis on prehistoric sites. In total, 45 sites of aboriginal occupation and several early historic Euroamerican homestead sites are described. Several locations were found on Popular Creek, East Fork Poplar Creek, and White Oak Creek. Only one site (40RE132) is located in White Oak Creek watershed above White Oak Dam. This is in the area of Burial Ground 6 (see Fig. 11), and much of the site was apparently destroyed during excavation and disposal operations. A total of 204 artifacts were recovered at the site. One other site (40RE131) is located adjacent to White Oak Creek below the dam while a second

(40RE27) is located near the confluence of White Oak Creek with Clinch River. None of these sites appear to be of special significance or interpretative value (see Fielder, 1974).

Land use on the Oak Ridge Reservation has changed with time. Aerial photographs taken in 1942 indicate that approximately 43 percent of the area was comprised of fields and pasture, and the remaining areas were forested. In 1947, a reforestation program was began to replace timber harvested for construction of the Oak Ridge facilities and as a land management action. This program ended in 1960 after approximately 9 million pine seedlings had been planted in old field and open areas. By 1965 approximately 4,300 acres of shortleaf, loblolly, and eastern white pine plantations were contained within the Reservation (see Curlin, 1965).

The present allocation of Reservation land use among the plant installations is as follows: Research and Management (15,108 acres), ORNL (8,843 acres), Y-12 (3,632 acres), K-25 (5,645 acres), and UT-ERDA (3,786) for a total of 37,014 acres (USAEC, 1974). Buffer areas around each facility provide increased security and protection against accidental release of toxic materials as well as providing room for future expansion. Excluding the buffer areas, the remainder of the reservation is subdivided into 24 management units ranging in size from 400 to 1,200 net manageable acres (Curlin, 1965). Approximately 93 percent of the total manageable land (15,000 acres) is forested in pine (36%), upland hardwoods (32%), mixed pine-hardwoods (21%), and cedar and miscellaneous species (11%) (USAEC, 1974).

In 1975, Oak Ridge Operations, U. S. Energy Research and Development Administration published a land-use plan for the Oak Ridge Reservation. This document (USERDA, 1975) contains detailed and categorical information on land and water resources, facilities, current usage, and both firm and tentative future commitments for land use on the Reservation.

I. SITE CHARACTERISTICS

B. Assessment

It is highly unlikely that any particular geographic locality could be found which is perfectly suited for operations involving all facets of the nuclear fuel cycle, especially the disposal of radioactive waste materials. The Oak Ridge Reservation is no exception. Many of the site characteristics presented in the preceding text are favorable for storage and disposal operations, whereas others are obviously detrimental and some are not important considerations.

The physiographic and topographic attributes of the area can be viewed as both favorable and unfavorable toward the operation of nuclear facilities and waste disposal. The rolling, hilly topography associated with restricted access permits isolation of the facilities from the public and favors establishment of buffer areas. In the event of an accident, existing topographic features would tend to enhance the confinement of impact. On the other hand, most of the landscape is composed of moderate to steep slopes with only a small percentage of gently sloping to flat surfaces. This obviously hinders excavation and construction activities. Additionally, and perhaps more importantly, the topography, when interpreted in relation to climatology, geology, hydrology, and pedology, exerts a more profound influence upon site selection for disposal facilities. In essence, the only areas suitable for such facilities (shallow land disposal) are confined to the valleys. Thus at least 50 percent of the landscape must be excluded from consideration on this basis alone; when geologic and hydrologic criteria are applied most of this remaining land area is found to be undesirable.

The geologic conditions of the Oak Ridge area are complex. The structural elements associated with folding and faulting greatly complicate tracing of stratigraphic units in three dimensions. Furthermore, the presence of joints and fractures associated with the tectonic activity provide pathways for subsurface movement of materials entering the ground-water system. The accurate prediction of rates and directions of material transport under these conditions is extremely difficult at best. Lithologic characteristics are such that many stratigraphic units contain significant amounts of soluble carbonates. Circulation of subsurface water can, with time, appreciably increase the size and interconnection of voids, thereby enhancing subsurface migration. A layer of weathered, residual material mantles much of the bedrock. The physical and chemical characteristics of this residuum depend upon the lithologic characteristics of the bedrock and the specific weathering processes which have altered the parent rock. In general, these unconsolidated weathering products are more permeable and, as a consequence, infiltration of precipitation is enhanced. This is evidenced by the fact that surface runoff-precipitation relationships indicate an appreciable interflow or shallow, subsurface component. These facts, combined with the abundant supply of precipitation, ensure a large quantity of water passing through the zones which could be used for shallow land burial.

The Conasauga Shale, because of its ion exchange capacity, lesser permeability, ease of excavation, topographic position, and other characteristics has been selected as the best suited stratigraphic unit for disposal purposes. However, in recent years, many of the climatic, geologic, and hydrologic characteristics of the site location have been more thoroughly investigated and their deleterious effects noted. As a result, this geologic unit is currently less appealing as a receptacle for radioactive wastes than was once believed. Current investigations indicate that containment is incomplete and significant quantities of radioactive contaminants from buried wastes are entering the Clinch River through the subsurface-surface drainage pathways of White Oak Creek watershed.

In general, the natural conditions within White Oak Creek Watershed are not conducive for shallow land burial of radioactive wastes. However, considering the overall site characteristics, the areas currently in use are the most desirable of what land is available. Leakage can be reduced significantly by applying corrective measures to decrease ground-water movement through the burial grounds.

II. FACILITIES

A. Description

1. Introduction

Solid radioactive wastes generated at the Oak Ridge National Laboratory are collected in suitable containers and periodically transported to one of the solid waste storage areas (SWSA), commonly called burial grounds, where they are stored either above or below the land surface in either a "retrievable" or "semi-retrievable" form.*

There are a number of different types of containers used for the collection of wastes at the point of origin. These vary in size and construction depending upon the character of the radioactive materials involved. In some cases the containers are reusable and, with proper precautions, are emptied into larger receptacles for transport. In other cases, the container is stored along with the waste.

There are six burial grounds located on Energy Research and Development Administration (ERDA) reservation in the vicinity of ORNL. Three of these areas are inactive, and two (5 and 6) are currently in use, although burial ground 3 is now used only for aboveground storage of contaminated equipment that may be salvageable. The available space for semi-retrievable storage in burial ground 5 is nearly exhausted, although the area is still used for retrievable aboveground and belowground storage.

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*In this context "retrievable" means the material is stored in durable containers in such a fashion that recovery of the material in the foreseeable future is facilitated. "Semi-retrievable" means that no particular attempt has been made to facilitate recovery, i.e., the material has simply been buried.

Burial ground 6 was opened in 1969, and contains sufficient space to handle the anticipated needs of the Laboratory until a more efficient method of handling solid waste is devised. In Melton Valley, south of ORNL, where current operations are being carried on, there are few, if any, areas remaining that are suitable for use as solid waste storage areas.

2. Sources and Types of Wastes

Solid radioactive wastes are generated in a number of ways at ORNL. The largest volume consists of radwaste or "laboratory trash" (glassware, paper, rags, or other miscellaneous material) which is either contaminated or suspected to be contaminated. Other sources include solid residues from various physical and chemical processes. Frequently, contaminated items of equipment, machinery, tools, tanks, valves, pipes, etc., that are no longer needed are disposed of. Often, decontamination of each item to a level sufficiently low for conventional disposal is uneconomical; these items are disposed of by burial. An additional potentially high-volume source of solid waste is soil, concrete, and various types of building materials that have become contaminated as a result of leaks, spills, or by other means. These wastes also are usually buried.

At one time the Laboratory's solid waste diposal areas were designated by the Atomic Energy Commission* as the Southern Regional Burial Ground, and during the period from 1955 to 1963, about one million cubic feet of solid waste from various off-area sites were disposed of by

*Precedent organization to ERDA.

underground burial in burial grounds 4 and 5. Moreover, the waste storage areas have been, and continue to be, used occasionally for the disposal of waste from other government sites. The exact character of much of this previously received waste is unknown.

Solid radioactive waste can be classified by physical size and shape, by type of contamination (i.e., β-γ,α, or fissile), and by the extent of contamination as measured by the radiation intensity at the surface of the package.

Wastes handled routinely at the Laboratory can conveniently be classified for the purpose of storage in the following manner:

(a) Fissile alpha waste* - solid waste that exceeds a concentration of 10 μCi/kg of alpha particle activity and is associated with fissionable isotopes. This category includes the transuranium isotopes (primarily Am, Cm, and Pu) as well as the isotope ^{233}U. These materials must be handled in such a manner as to contain the (generally long lived) alpha activity as well as with due regard for the criticality problems arising because of their fissile character. These materials originate primarily in the transuranium processing facility and as a result of fuel reprocessing operations. Frequently, beta-gamma activity is associated with these nuclides, and in some cases, notably those involving "even-even" nuclides of heavy elements, spontaneous fission occurs, thus creating a source of neutrons.**

*Corresponds to Transuranium-Contaminated Solid Waste as defined in AEC Appendix 0511, Part 1, B.23.a.

**In this connection, beryllium and deuterium become neutron sources when exposed to photons of sufficient energy. Because of this possibility, combinations of these nuclides with high energy gamma emitters must be handled in a special way.

(b) Fissile non-alpha waste - solid waste that contains one gram or more of essentially non-alpha-emitting fissionable material regardless of concentration, or more than one gram per cubic foot of the same material regardless of quantity. In this context the term fissile applies almost exclusively to ^{235}U, because the other fissionable isotopes fall into the category of fissile alpha materials. Sources of ^{235}U waste include various metallurgical operations, residues from instrument applications, hot cell operations, and various research and analytical activities. The central problem here is to prevent inadvertent criticality.

(c) General radioactive waste (radwaste) - solid waste that is neither fissile alpha nor fissile non-alpha as defined above. In general, this waste will contain beta-gamma activity and/or nonfissile alpha activity (such as Po, Th, Ra, ^{238}U, etc.) and originates in many places in the Laboratory: reactor sites; radioisotope operations; particle accelerator areas, hot cell operations; various physical, chemical, and biological research areas, and analytical laboratories. It constitutes by far the bulk of the solid radioactive waste generated at the Laboratory.

General radwaste is further divided into two types depending upon the intensity of the radiation at the surface of the package. "Low level radwaste" has a radiation intensity less than 200 millirads/hr, and "high level radwaste" an intensity greater than 200 millirads/hr.

Solid radioactive wastes that are handled according to the normal procedures developed for the three classes described above are designated as "routine" wastes. Occasionally, a circumstance arises where solid material must be handled in a special manner, for example, because an item is too large or awkward to be accepted in a routinely used container or because the radioactivity level is extremely high. In such cases, special procedures are developed to handle the situation, and wastes dealt with in this fashion are termed "non-routine". Non-routine wastes are classified in the same fashion as routine wastes, and all normal precautions are taken as well as any additional precautions dictated by the special handling procedures required.

Quite frequently both routine and non-routine wastes contain mixtures of two or more of the above classes, that is, fissile waste may be accompanied by beta-gamma emitting fission products, or both transuranium nuclides and ^{235}U may be present in the same package. Other combinations can also occur. In such cases the waste material is treated with due regard for all of the components present.

3. Storage Facilities

Solid fissile alpha waste, which consists primarily of transuranium isotopes and ^{233}U, is packaged in a manner appropriate to the radiation intensity associated with the waste. All of this material is now being stored in the retrievable mode.

A number of different types of facilities are used for the storage of solid fissile-alpha wastes. These range from trenches in which the cask of material is placed and covered with earth, to stainless-steel-lined auger holes for cylindrical drums or packages of various diameters, to 85% below-ground roofed buildings for 55 and 30 gal metal drums. The choice of facility depends on the origin of the material and on the intensity and character of the radiation involved.

(a) Cask storage. That waste which is accompanied by high levels of beta-gamma or neutron emission is usually packaged at the source in a reinforced concrete cask (Figs. 16a, 16b, and 16c). These casks are available with three wall thicknesses, 4-1/2, 6, and 12 in. The loaded casks are transported from the point of origin by tractor-trailer and placed in unlined trenches (similar to those described in the next section entitled "Disposal Facilities") by means of a mobile crane. Casks are segregated by trench according to burnable and non-burnable waste content. The trenches are backfilled and can be identified by means of the metal casing or resurveyed from engineering data. Records are kept of the location and contents of each trench.

(b) Drum storage. In cases where the radiation reading at the surface of the container is less than 200 millirads/hr, the fissile alpha waste is stored in stainless steel drums (the initial practice of permitting black iron drums to be used has been discontinued). These are held in a staging area, Building 7823, until a sufficient number of drums is accumulated to warrant opening a cell of the Retrievable Waste Storage Facility, Building 7826.

Building 7823, a make-shift shed constructed without benefit of formal design and primarily using discarded structural steel, is intended for temporary storage only. It is 50 ft wide by 80 ft long two-thirds below grade, has a gable roof open at each end with a truck entrance on the south side of the building. The walls are curved galvanized metal culvert sections of 12-gauge corrugated steel. The roof is 0.032-in. corrugated aluminum with four sections of plastic skylight. There is an interior ceiling of 9-gauge galvanized steel wire fencing located

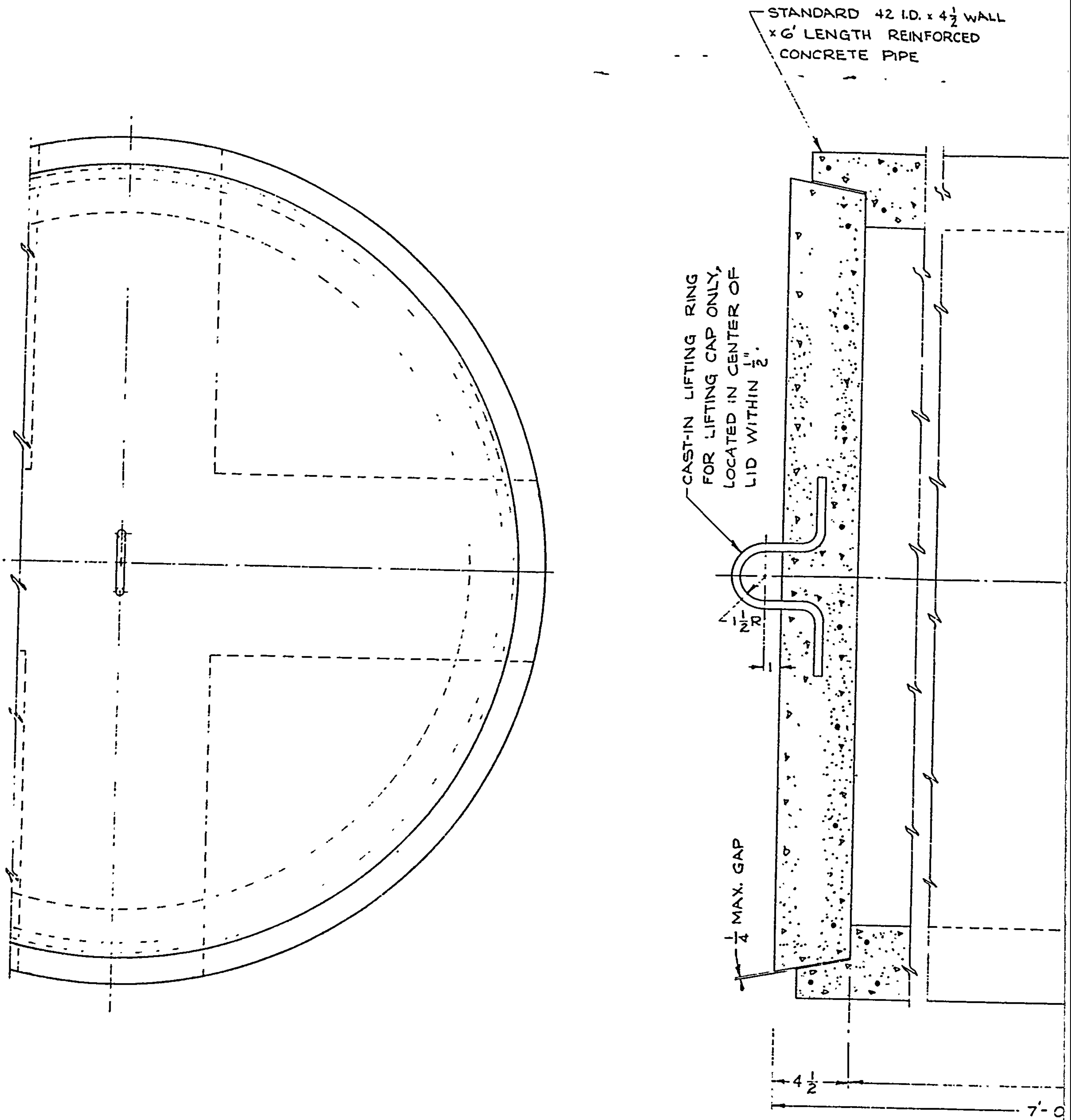
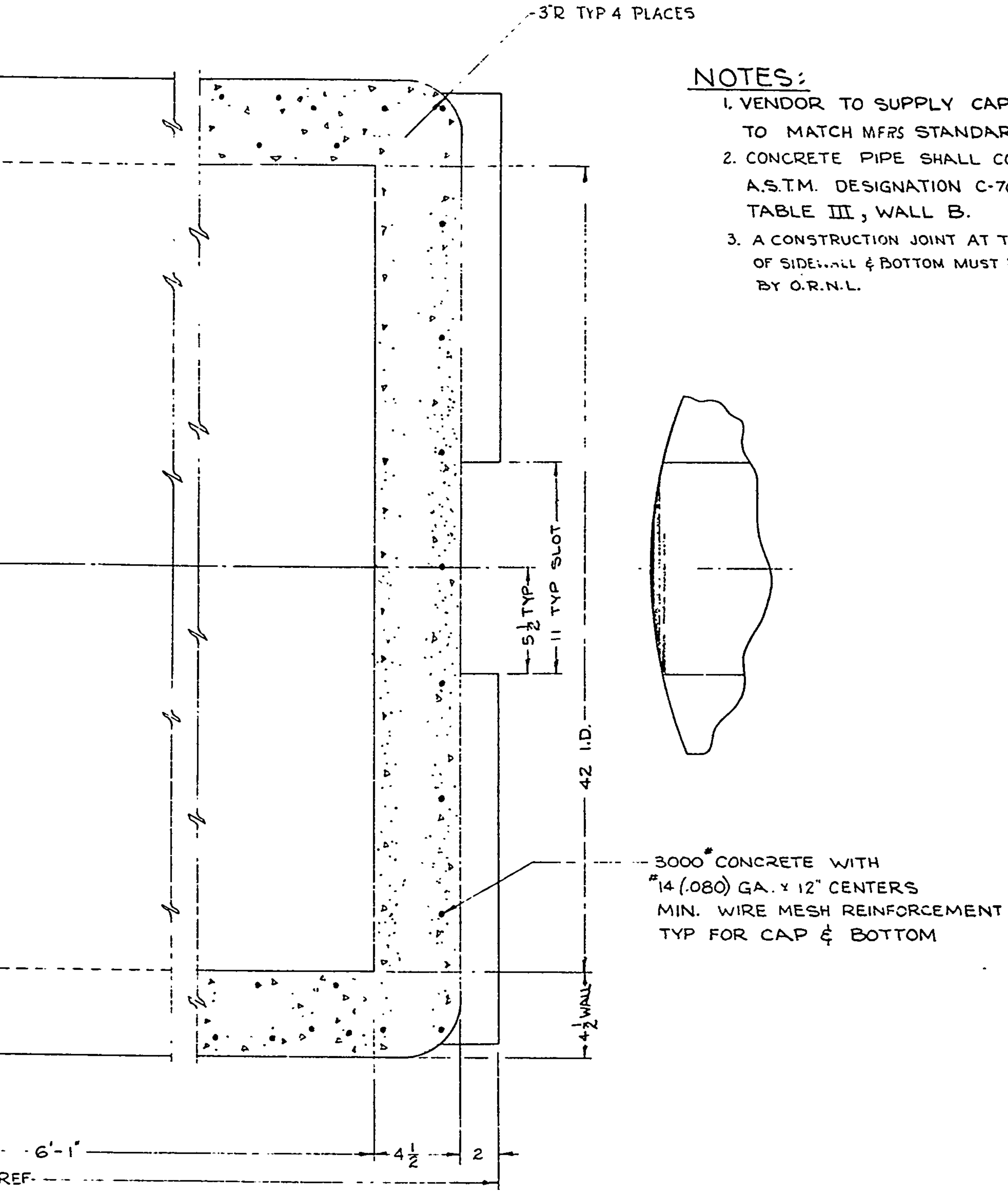


Fig. 16a. Concrete cask for storage of



NOTES:

1. VENDOR TO SUPPLY CAP TO MATCH MFRS STANDARD PIPE.
2. CONCRETE PIPE SHALL CONFORM TO A.S.T.M. DESIGNATION C-76-63T TABLE III, WALL B.
3. A CONSTRUCTION JOINT AT THE JUNCTION OF SIDEWALL & BOTTOM MUST BE APPROVED BY O.R.N.L.

ssile alpha wastes — thin walled.

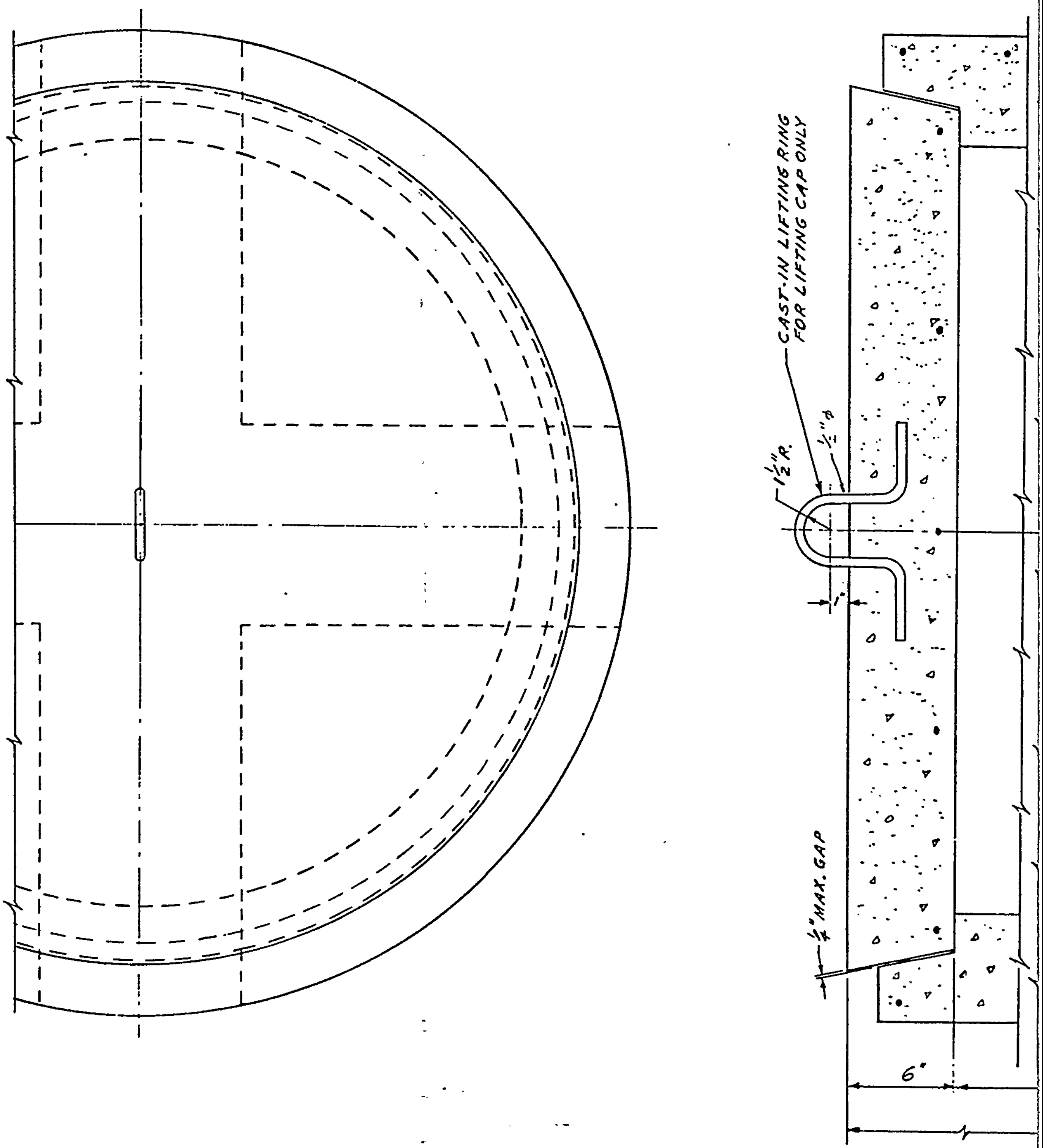
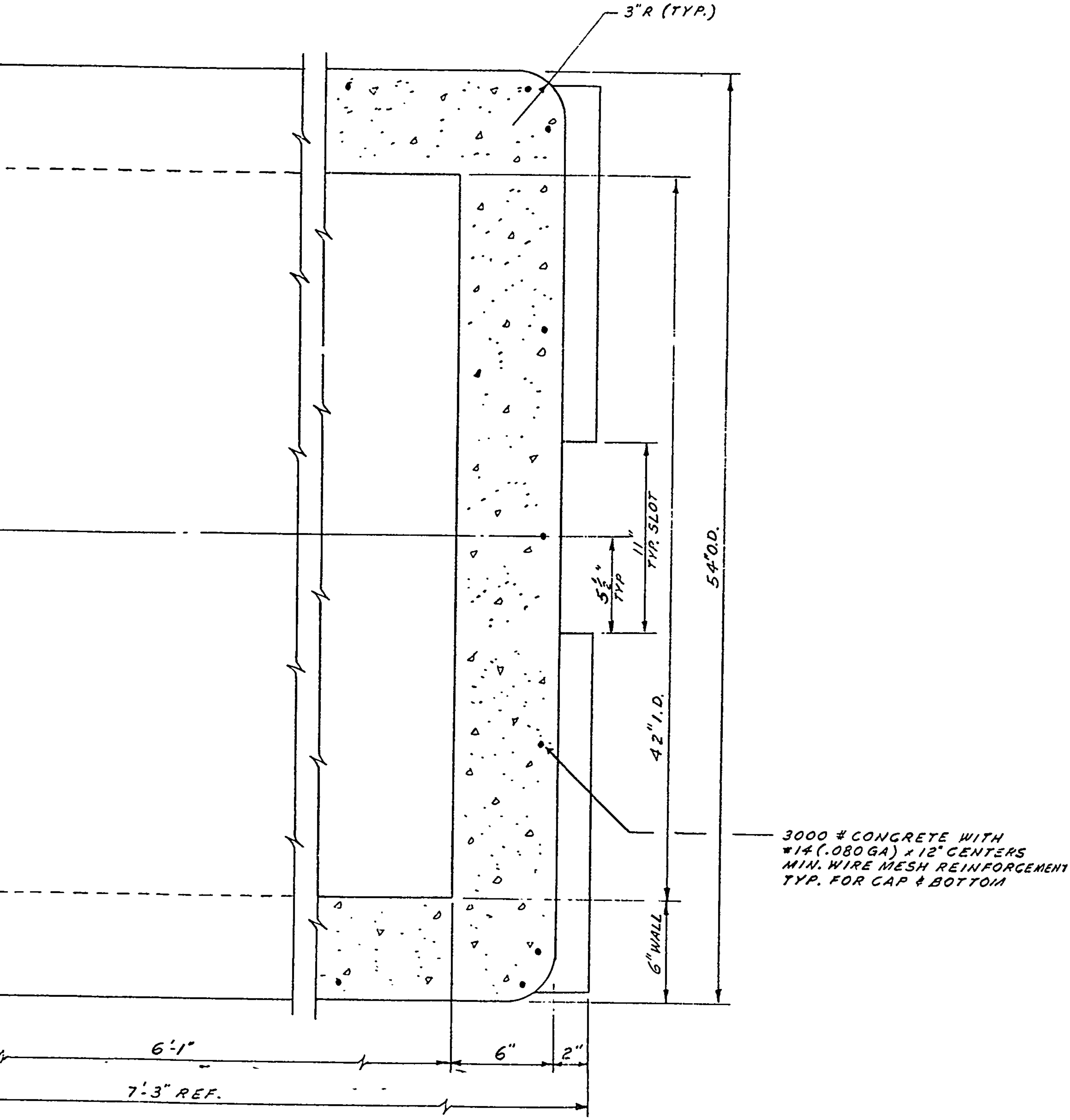
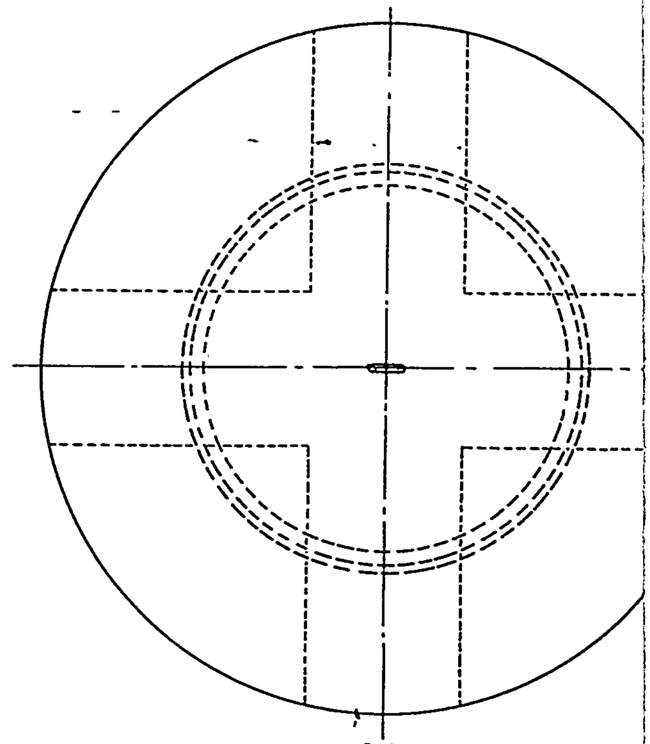


Fig. 16b. Concrete cask for storage o



fissile alpha wastes — intermediate walled.



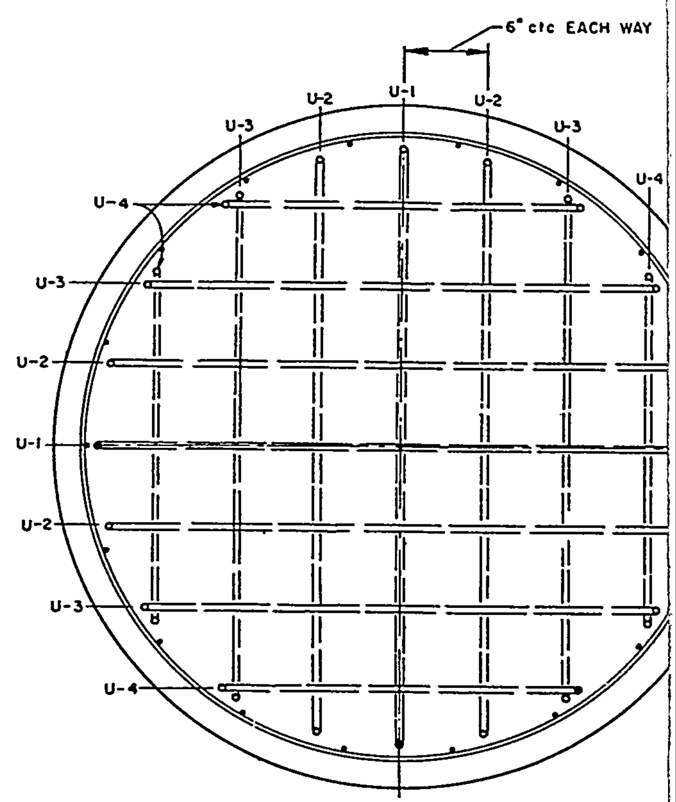
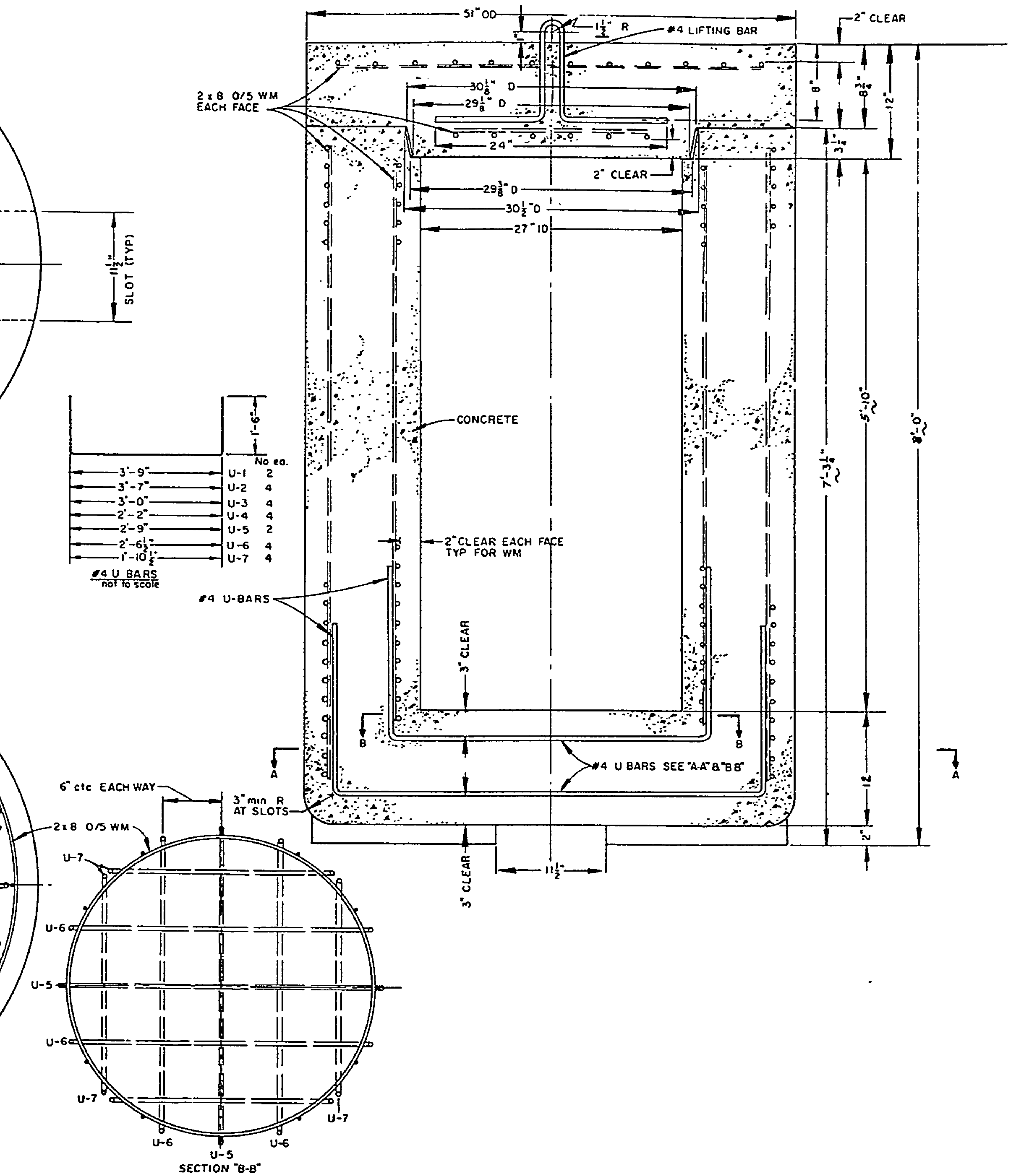


Fig. 16c. Conc



te cask for storage of fissile alpha wastes — thick walled.

14 ft above the crushed rock floor. There are no utilities inside the building. This original storage facility for drums has been replaced by the Retrievable Waste Storage Facility, Building 7826.

Building 7826 (Figs. 17, 18, and 19) is a one story reinforced concrete and concrete block structure approximately 38 ft x 57 ft x 13 ft high designed for resistance to the ERDA Design Basis Tornado and constructed specifically for storing drums of waste material. There are 24 pits or cells which accommodate 55 gal drums - 64/cell (16/layer, 4 layers/cell). About 85% of the structure is below grade. There are no utilities inside; there is a sump with gravity drain at the bottom of each cell. Access is by removal of roof sections, each section accommodates two cells.

Criticality control of these materials is accomplished by imposition of the restrictions given in Table 2 that specify the maximum quantity of fissionable materials* permitted in each type of container. These restrictions are consistent with the requirement that the concentration of fissionable material shall not exceed 5 g/ft^3, at which level an infinite array of such containers has a multiplication constant well below unity (ORNL Criticality Committee to A. M. Weinberg, 1971). In any case, where the amount of fissionable material to be stored exceeds the quantities listed in Table 2, or 5 g/ft^3 for other containers, the originator of the waste must obtain prior approval from the ORNL Criticality Committee. Under certain circumstances this Committee may, after due consideration, modify the requirements of Table 2 for individual packages.

*Fissionable material means ^{233}U, ^{235}U, or ^{239}Pu. Very small quantities of transuranium isotopes may be present, some of which are fissionable. Control of these materials is discussed in part III.

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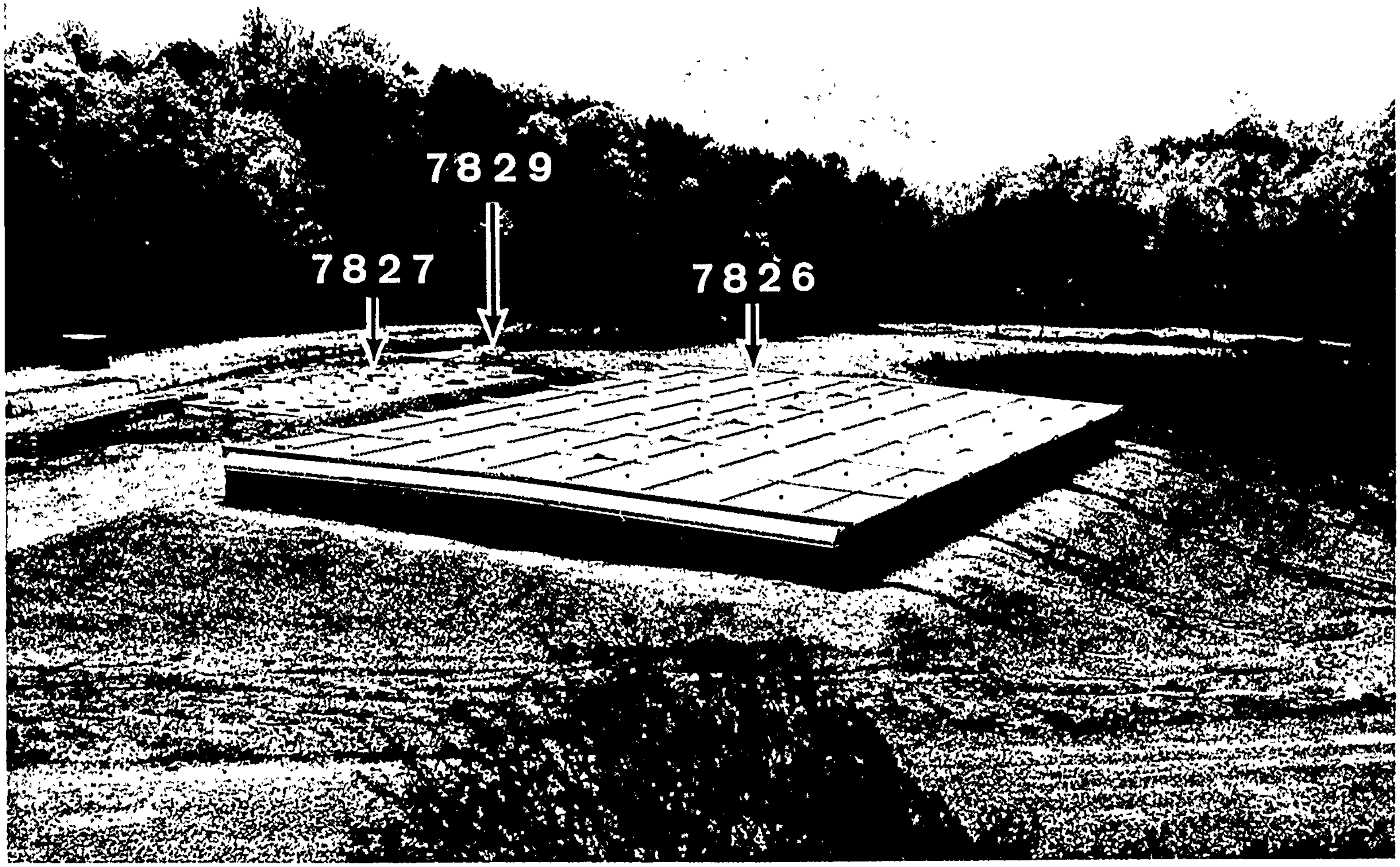

Fig. 17. Retrievable waste storage facilities.

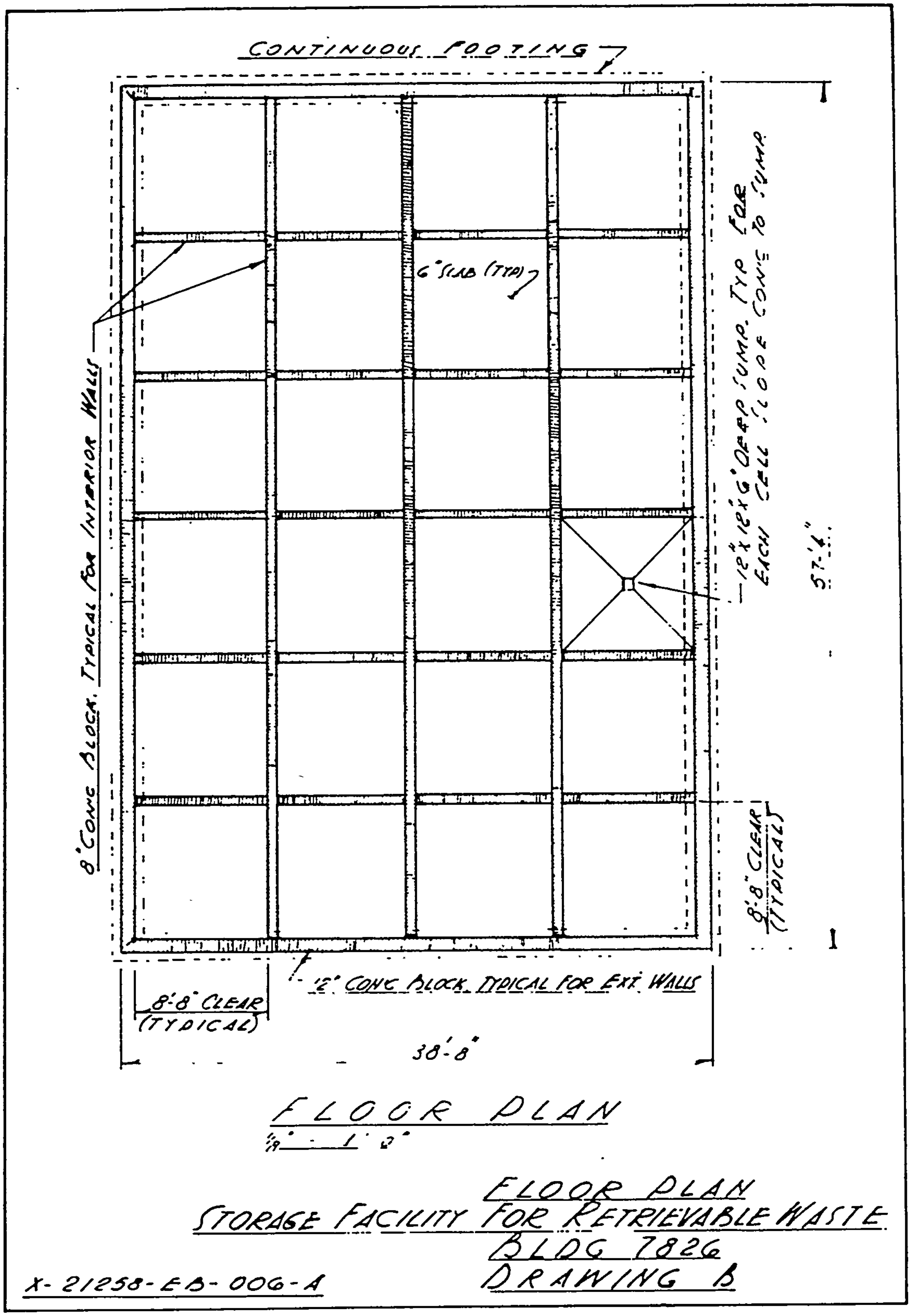

Fig. 18. Retrievable waste storage facility - plan view.

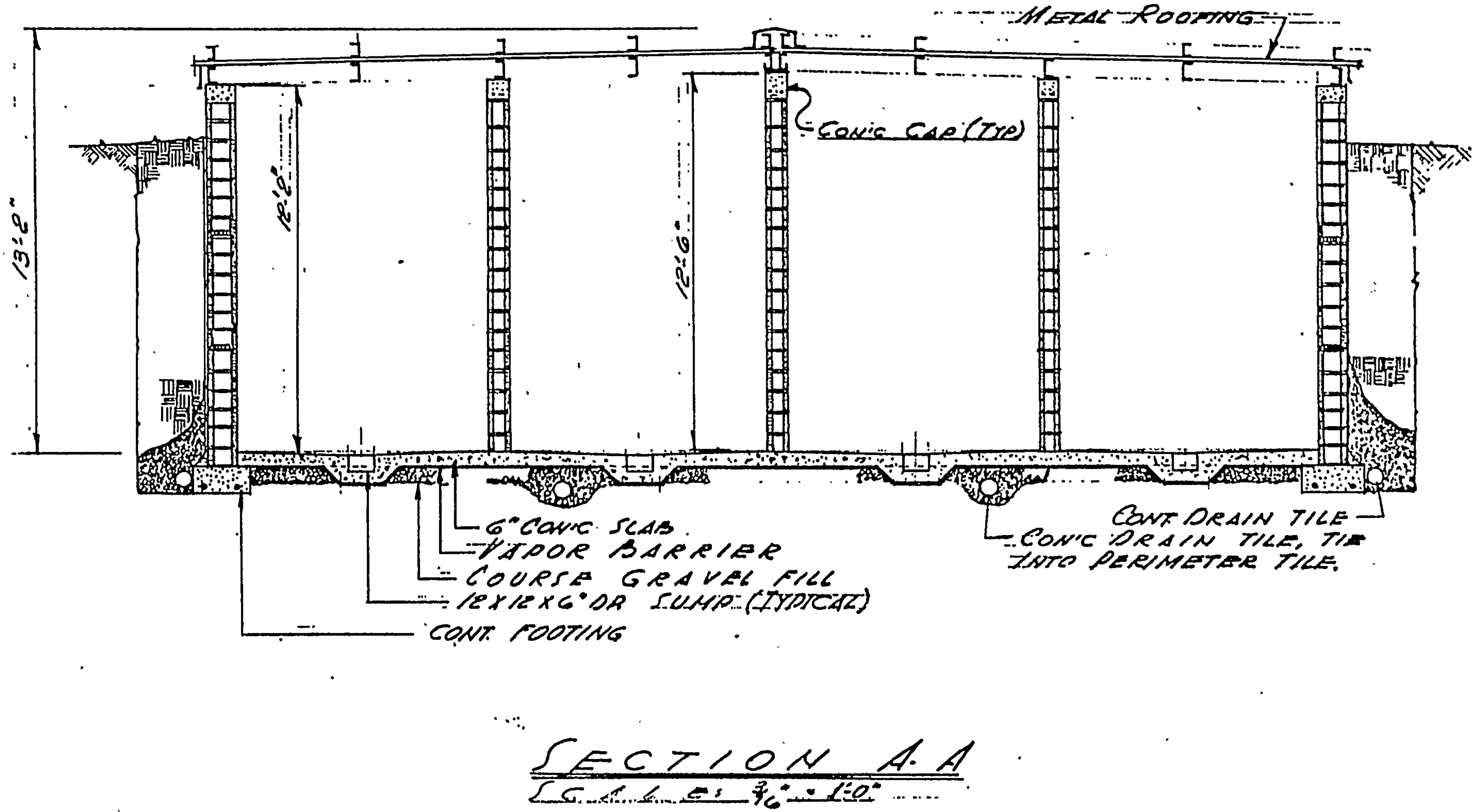

Fig. 19. Cross section of storage facility for retrievable waste (Building 7826).

Table 2. Amount of Fissionable Material Permitted by Container Type

Container Type	Maximum Fissionable Material (g)
30-gal drum	20
50-gal drum	36
Concrete cask (thin walled)	200
Concrete cask (intermediate walled)	200
Concrete cask (thick walled)	200

(c) Stainless steel wells. In some cases fissile alpha material with high background readings is stored in stainless-steel-lined auger holes of various diameters - normally 8, 10, 12, 14, 16, or 20 in (Fig. 20) - and drilled to meet the appropirate hydrological requirements. The liners are rolled from 16-gauge stainless steel and seam-welded; the bottoms are then welded in. All welds are dye-checked. The liners are provided with concrete collars and stainless steel caps. For criticality control, spacing between holes is not less than 3 ft, edge to edge, and the isotope content per hole is limited to 200 g unless prior approval is obtained from the ORNL Criticality Committee.

The holes are used to store waste contained in stainless steel 30- or 55-gal drums or in other suitable stainless steel cylindrical containers. When full, the hole is plugged with a removable stepped concrete plug and a metal tag is provided for identification purposes. Records are kept of the contents of each hole.

Buildings 7827 and 7829 are SS lined well facilities of improved design for storing fissile-alpha waste material with associated high beta-gamma background. The former has 30 wells, fifteen 15 ft deep

Fig. 20. Stainless-steel lined auger holes.

and fifteen 10 ft deep; each group is comprised of an equal number of 8", 16", and 30" diameter holes with stepped plugs (Figs. 17, and 21). The latter contains ten wells each 12" in diameter by 15 ft deep with stepped concrete plug.

Criticality control is assured by spacing of holes and limits of isotope contents per hole as mentioned above.

4. Disposal Facilities

Fissile non-alpha waste and general radwaste are normally disposed of by depositing the contaminated material below grade in unlined trenches and/or auger holes. The earth spoiled from the excavation is used to backfill the hole at close out. The excavation for fissile non-alpha waste is capped with concrete.

(a) Trenches. All trench development is accomplished using applicable engineering practices, and due consideration is given to the topographical and hydrological features of the site. The trenches are approximately 50 ft in length and 10 ft wide. The depth is normally 10 to 15 ft and is always limited to at least 12 in above the known high water table. If, due to unanticipated circumstances, the excavation falls below the water table, the trench is backfilled with Conasauga Shale (native soil) to a depth of at least 12 in above the existing water.

The trenches are graded to slope toward one end (approximately 1/2 in. per foot of length). A 6-inch diameter, perforated, corrugated metal casing, inserted vertically into the trench and extended above the surface of the ground, serves as a monitoring well. A typical layout of a disposal trench is shown in Figure 22.

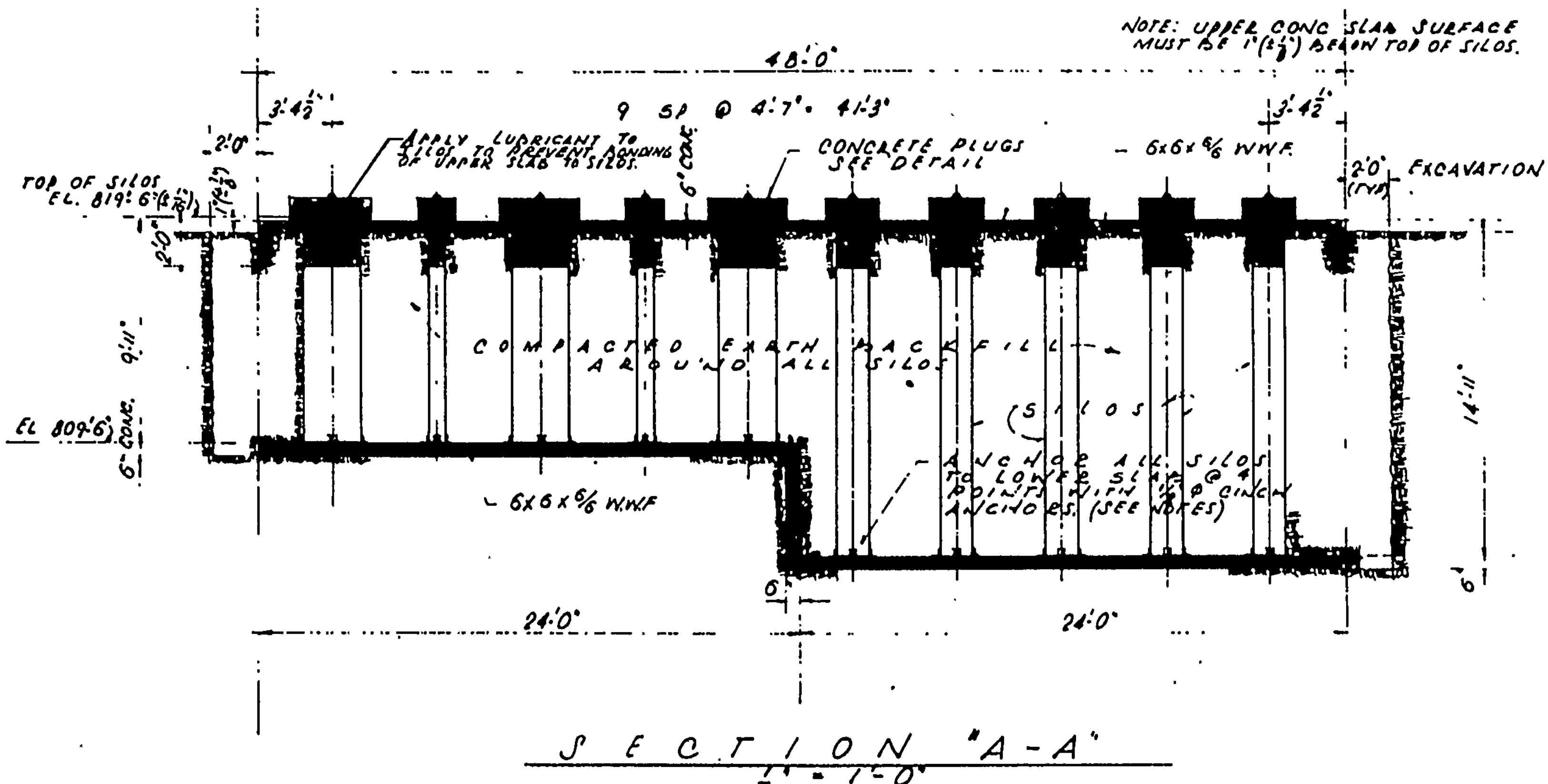

Fig. 21. High beta-gamma-alpha storage facility.

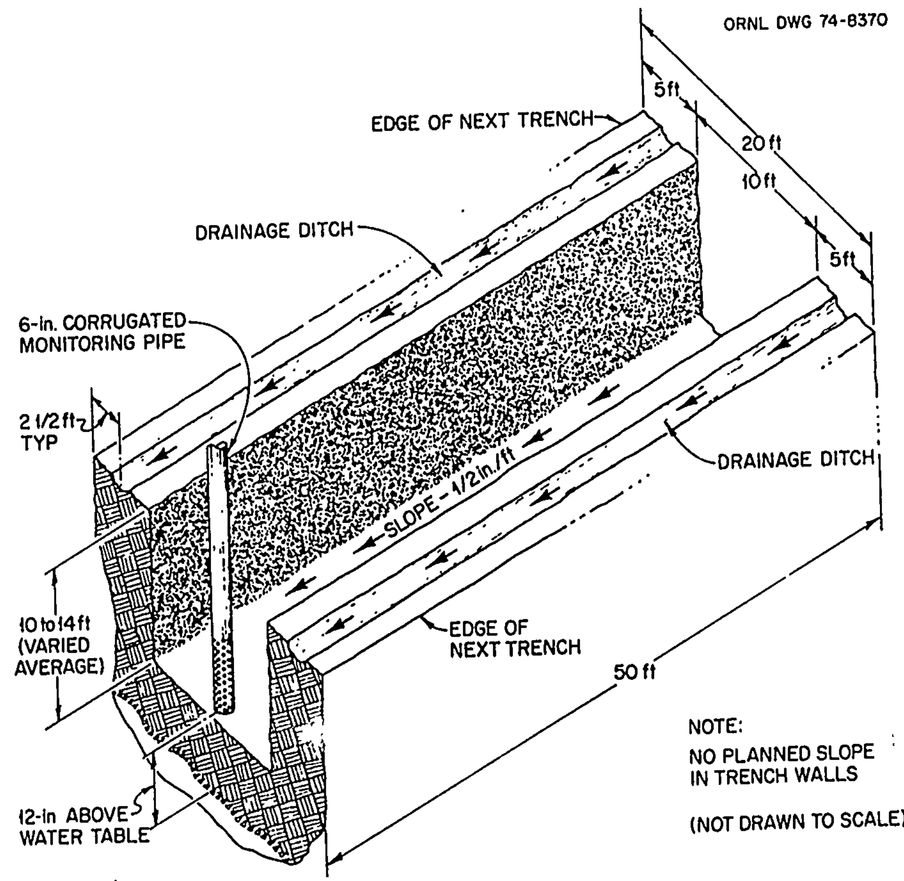

Fig. 22. Typical disposal trench layout.

Surface water drainage is controlled by ditching around the trenches to meet prevailing surface drainage requirements. Appropriate barricades are provided adjacent to the open portions of the trenches to ensure personnel safety.

Once the trench is filled to within 3 ft of grade, it is backfilled with earth cover over the waste. If periodic sampling of the well or other symptoms indicate that additional action is required to prevent the entry of water, appropriate steps are taken. The metal well casing is also used as a trench marker and may have a metal tag identifying the trench by number attached to it. All trench details are maintained on as-built drawings, and a log describing the history of the trench is maintained.

Note that the foregoing procedures represent current practices in burial grounds 5 and 6. Less careful attention was given to the selection of the other storage areas, and there was much less thought involved in the design of the trench configuration.

(b) Auger holes. Auger holes of various diameters (normally 24 and 41 in) and depths are sunk into the Conasauga Shale of the burial areas. Depth is determined by several factors, the primary one being available hydrological data pertinent to the location.

A minimum spacing of 3 ft (measured edge to edge) between holes is maintained and a restriction of 200 g per hole is imposed for criticality control. Prior approval of the ORNL Criticality Committee is required before this limit is exceeded.

Contents of these auger holes are logged and records are maintained; when filled the holes are capped with concrete. Hole locations are recorded through civil engineering survey.

5. Settling Basins (Waste Ponds)

There are three settling basins that have been used in past operations at ORNL. These basins are Waste Pond No. 1 (3524), Waste Pond No. 2 (3513), and the Homogeneous Reactor Test (HRT) Settling Basin (7556). The latter two facilities are shown on Figure 23. Waste Pond No. 1 lies north of and adjacent to Waste Pond No. 2 (process waste settling basin).

Waste Pond No. 1 is still in use and serves as an equalization basin for laboratory process waste prior to its treatment by the ion exchange facility. Before the ion exchange facility became operational in 1976 the pond served as an equalization basin for the lime-soda-clay treatment process. The liquid effluent from this treatment plant was pumped to the settling basin (Waste Pond No. 2) where the outflow was monitored before it entered White Oak Creek.

Waste Pond No. 2 has been receiving waste since 1944. In its early history it served as the primary settling basin before waste was released to White Oak Creek. From 1957 to 1976 it served as the settling basin for the effluent from the lime-soda-clay treatment plant. In 1976 when the pond was slated for decommissioning (with the advent of the ion exchange plant) bottom sediments were sampled and analyzed. These analyses show that the bottom sediments of Waste Pond No. 2 contain approximately 5 Ci (80 g) of $^{239,240}Pu$, 200 Ci of ^{137}Cs, and 33 Ci of ^{90}Sr (Tamura and others, 1977). Other radionuclides such as ^{60}Co as well as other transuranic elements and actinides are known to be present in significant quantities. However, an estimate of the curie content for these radionuclides is not available.

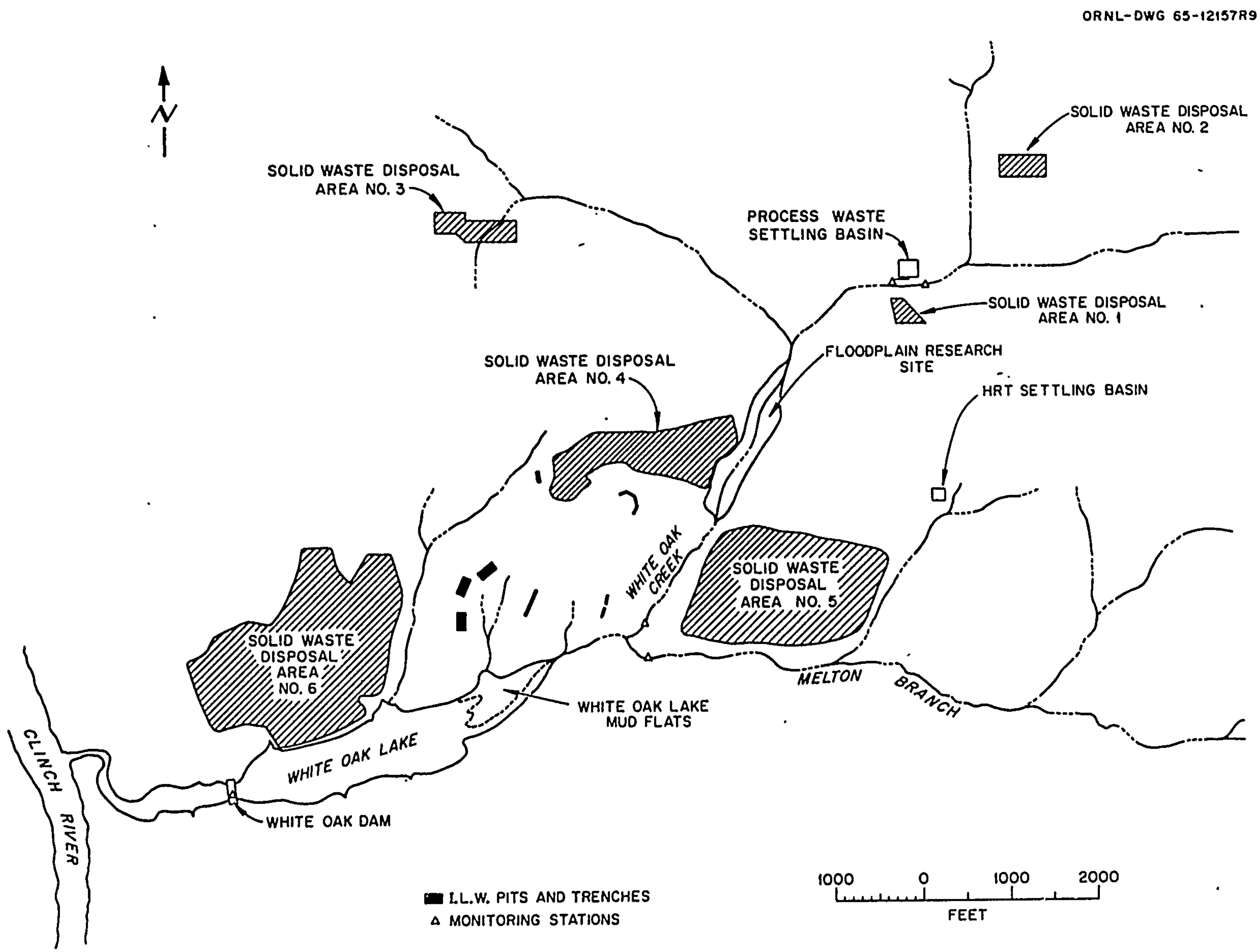

Fig. 23. Location of settling basins, seepage pits, and trenches, and solid waste dipsosal areas (burial grounds) in the White Oak drainage.

The concentration of radionuclides in the bottom sediment of Waste Pond No. 1 is expected to be higher than that of Waste Pond No. 2. This higher radioactivity arises from the fact that the first contact of the waste effluent with bottom sediment (soil) is in Waste Pond No. 1. This contact provides ample opportunity for sorption of radionuclides by the bottom sediment, thus, removing them from the waste stream prior to treatment. As yet the bottom sediments of Waste Pond No. 1 have not been analyzed and consequently no estimate of the curie content of this pond is available.

The HRT settling basin (7556) was used for disposal of low level liquid waste generated in the 7500 area. The basin is no longer in service and has been filled and is covered with asphalt. No records of its contents are available. However, approximately 10% of the ^{90}Sr entering Melton Branch originates from the settling basin and the contaminated floodplain adjacent to it. The floodplain soils also contain higher than background concentrations of ^{239}Pu.

6. Intermediate-Level Liquid Waste (ILW) Pits and Trenches

Since the beginning of operations at ORNL, soils have been used for the disposal of radioactive waste. Disposal consisted of land burial of solid waste in unlined trenches that were covered with soil or concrete. Based on this experience and with the knowledge that the Conasauga Shale is somewhat impermeable, the construction of pits for disposal of intermediate-level liquid waste was begun in 1951 (Fig. 24). The first experimental pit, pit 1, was opened in 1951 and closed almost immediately because of breakthrough of radionuclides due to the pit's poor location. A second pit, pit 2, was brought into operation in 1952, and for the

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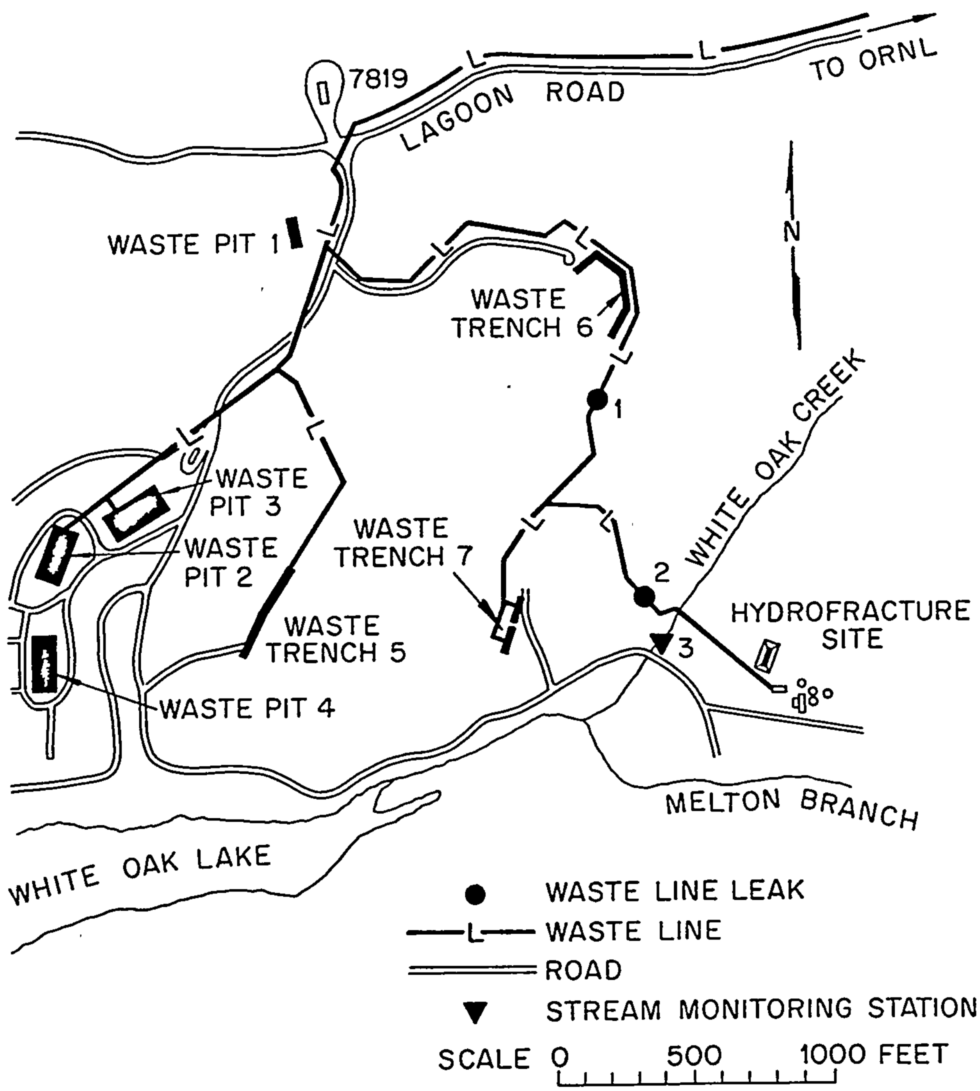

Fig. 24. Location of Intermediate-Level Waste (ILW) pits and trenches.

first time large quantities of intermediate-level waste was discharged into terrestrial pits. Pits 3 and 4 became operational in 1955 and 1956, respectively. The first covered trench, trench 5, was brought into operation in 1960, and trenches 6 and 7 in 1961 and 1962, respectively. Trench 6 was operated for only a short period in 1961 because of breakthrough of ^{90}Sr and ^{137}Cs (i.e., small amounts of ^{90}Sr and ^{137}Cs were observed in a seep below the trench which indicated rapid movement from the trench to the surface seep. This transport was attributed to ground-water flow through fractures in the Conasauga Shale). In 1962 pits 2, 3, and 4 and trench 5 were taken out of routine service; however, pit 4 was used for disposal of sludge from the Process Waste Water Treatment Plant until 1976. Trench 7 was taken out of service in 1965 as part of a plan to implement disposal of intermediate-level liquid waste by the process of hydrofracture. During the operation of the seepage pits and trenches, approximately 48 million gallons of waste, containing over 1 million curies of mixed fission products, were disposed of. Approximately half of this amount was ^{90}Sr and ^{137}Cs, with most of the remainder being ^{106}Ru. The waste contained considerably lesser amounts of ^{125}Sb, ^{60}Co, and other mixed fission products (Lomenick, Jacobs, and Struxness, 1967). The waste pits and trenches also contain transuranic elements and actinides. However, an accurate estimate of the curie content of these radionuclides is not available (see Table 3).

7. Solid Waste Storage Areas (Burial Grounds)

Burial of solid radioactive waste was initiated by the Manhattan District in the early 1940's at what is now ORNL. Locations for the first three burial grounds were selected primarily for convenience and

Table 3. Estimates of Materials to Trenches and Pits

Trench and Pit Number	Date Started	Date Closed	Activity (Ci)	Pu[a] (g)	Volume (gal)
Pit 1	1951	1951	400	--	12,300
Pits 2, 3, & 4[b]	1952	1976	500,000	300	30,720,700
Trench 5	1960	1966	300,000	100	8,271,000
Trench 6	1961	1961	1,000	2	125,000
Trench 7A	1962	1966	140,000	75	4,639,000
Trench 7B	1962	1966	120,000	75	3,847,000
	Total		1,061,400	612	47,615,000
	or rounding Total		1,000,000	600	48,000,000

[a] Based on minimal sampling and judging that most of the other waste not sampled was ∿ same in Pu content per unit volume.

[b] Discontinued pumping wastes to these pits in 1963 but the pits were used for dumping sludge from the Process Waste Treatment Plant until its showdown in 1976.

few, if any, geologic or hydrologic considerations entered into the siting decisions. However, as the volume of waste generated at ORNL increased and the quantity and variety of solids from offsite agencies expanded, greater attention was given to the selection of sites for storage areas.

It was determined that areas underlain by Conasauga Shale are best suited for underground storage (Stockdale, 1951), not only because the shale is easily excavated, but because the ion exchange properties of this material retard the migration of water-soluble nuclides through the soil. Because the area in Melton Valley, south of ORNL, is underlain by this formation, it has been used as a site for the three burial grounds (4, 5, and 6). Aerial photographs showing the locations of the six burial grounds are shown in Figures 25 and 26.

Of the six burial grounds at ORNL, only two are currently in use, although another (3) is used occasionally for aboveground storage of reusable equipment. Table 4 shows the current operational status of the ORNL solid waste storage areas.

Table 4. Operational Status of ORNL Solid Waste Storage Areas

Burial Ground	Operating Dates	Status	Land Used (acres)
1 and 2	1943-1946	Closed	5
3	1946-1951	Closed	7
4	1951-1959	Closed	23
5	1959-	Operating	33
6	1969-	Operating	68

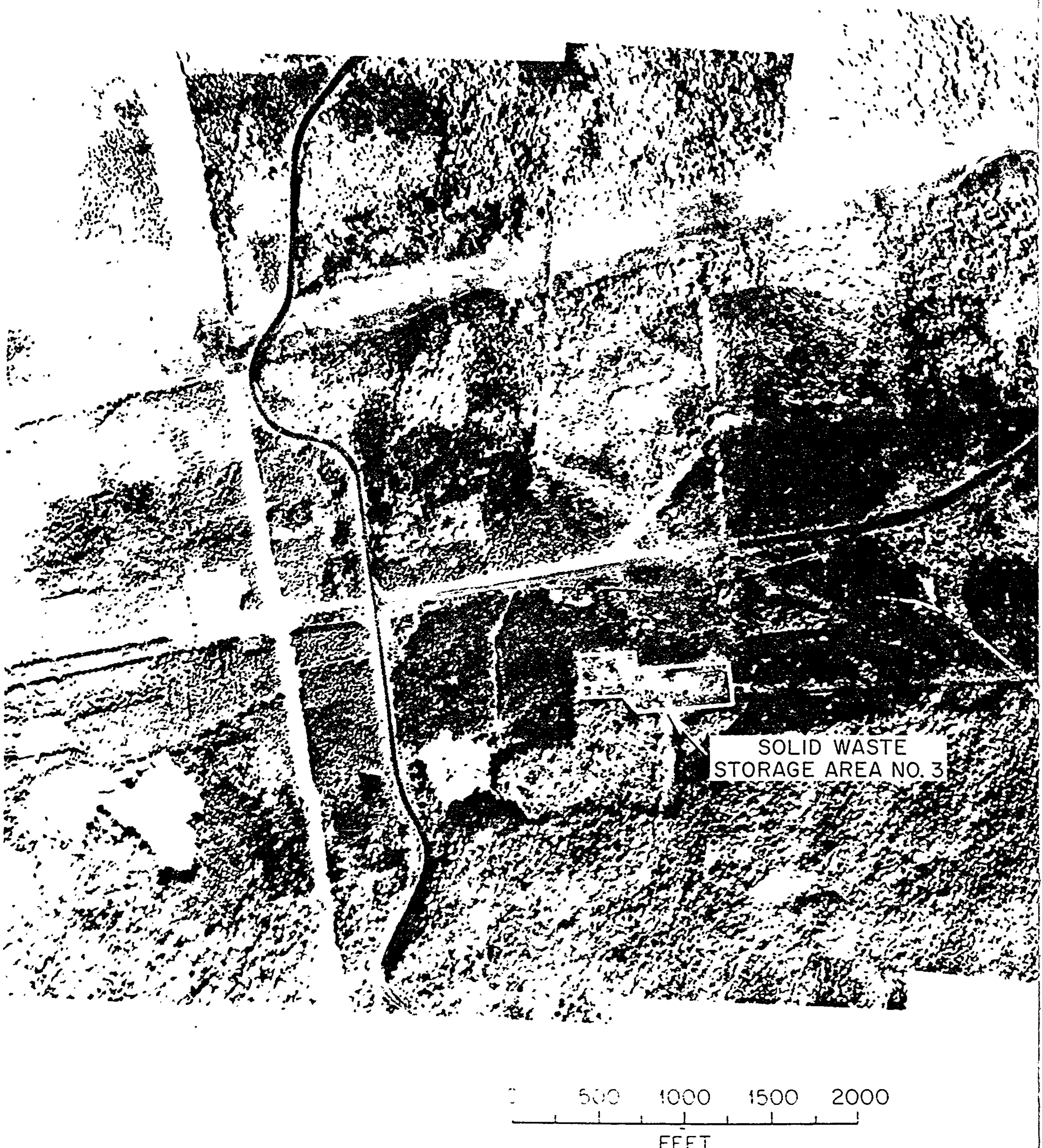

Fig. 25. ORNL-Bethel Valley waste d

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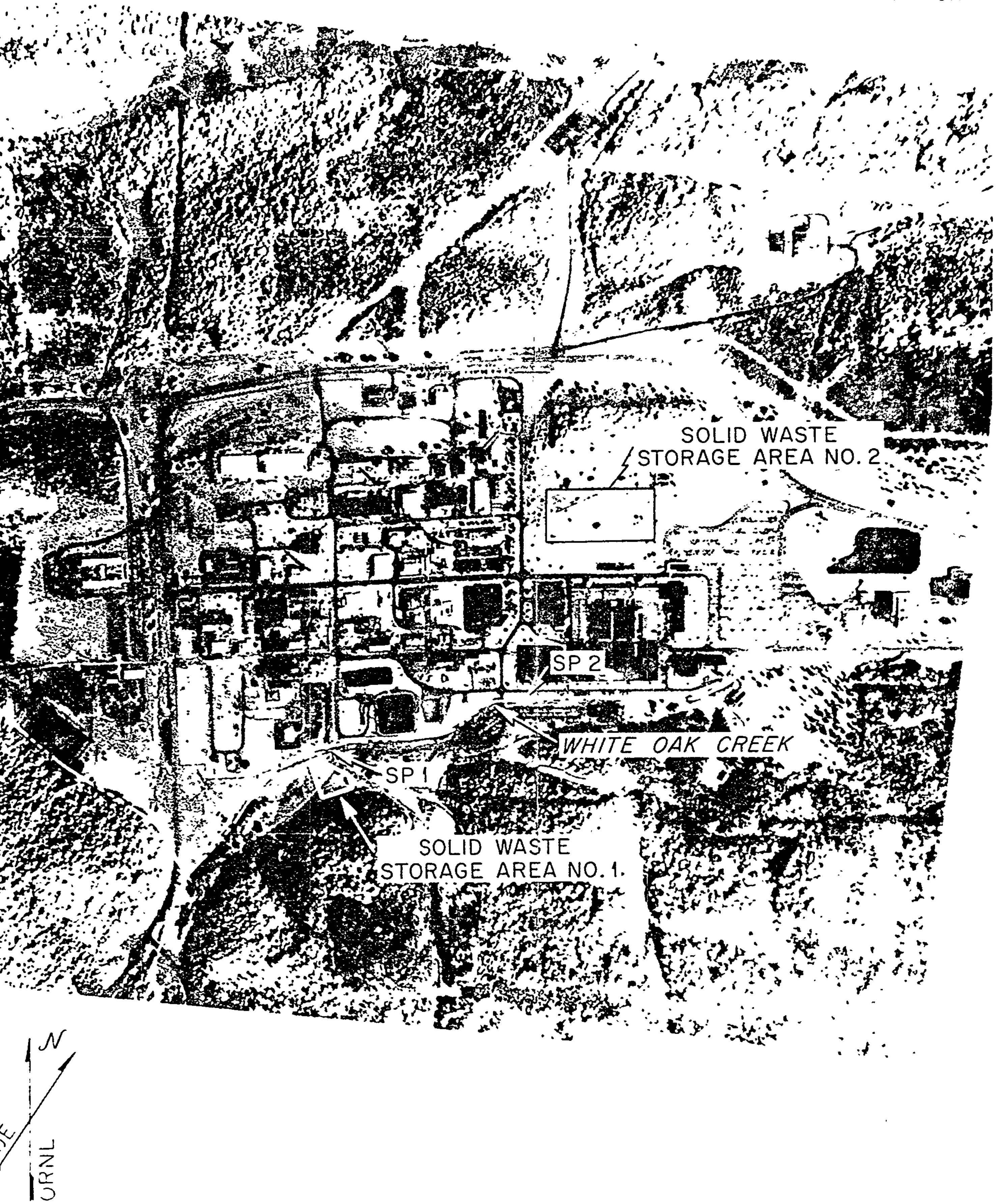


sposal facilities.

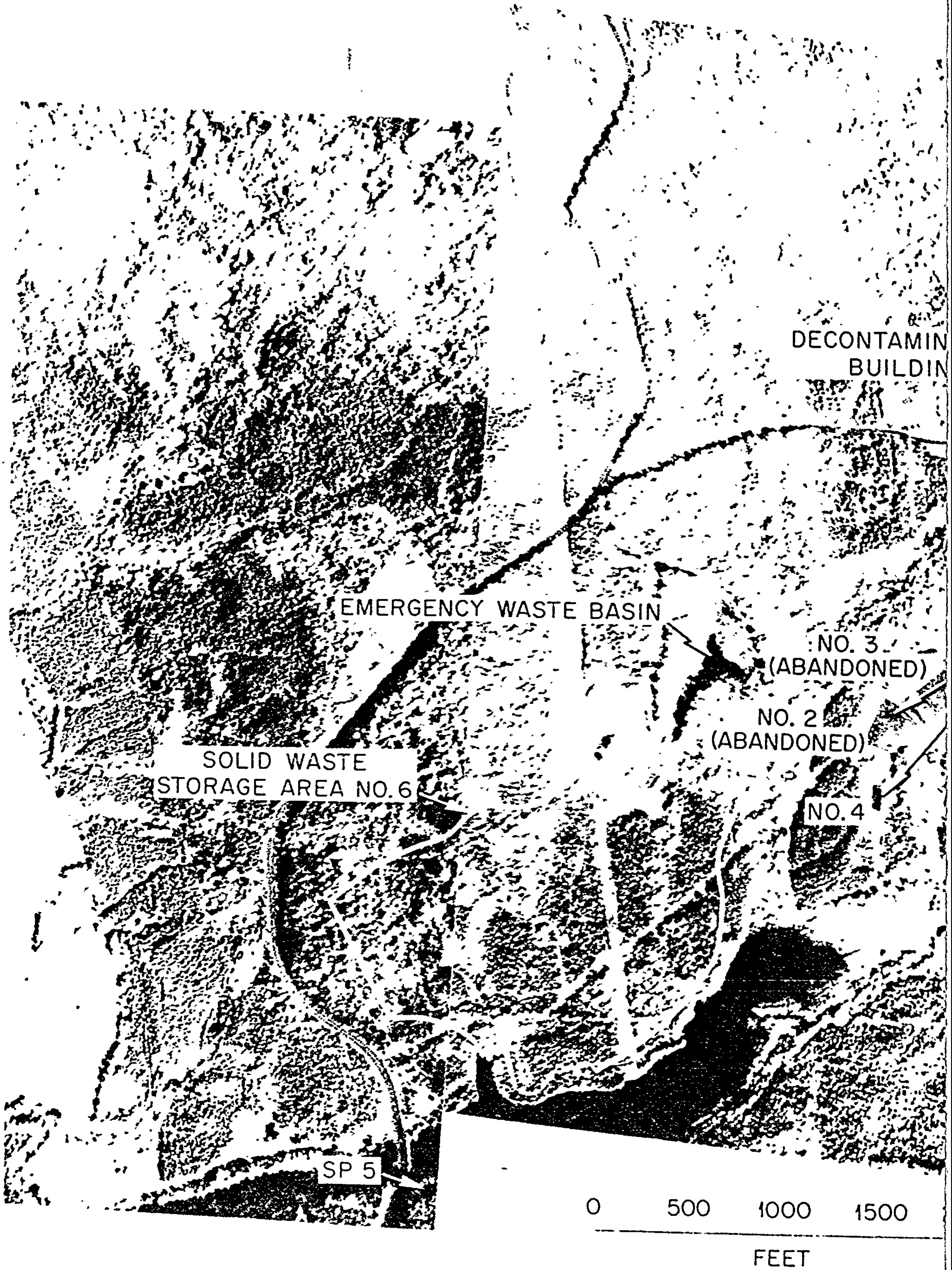
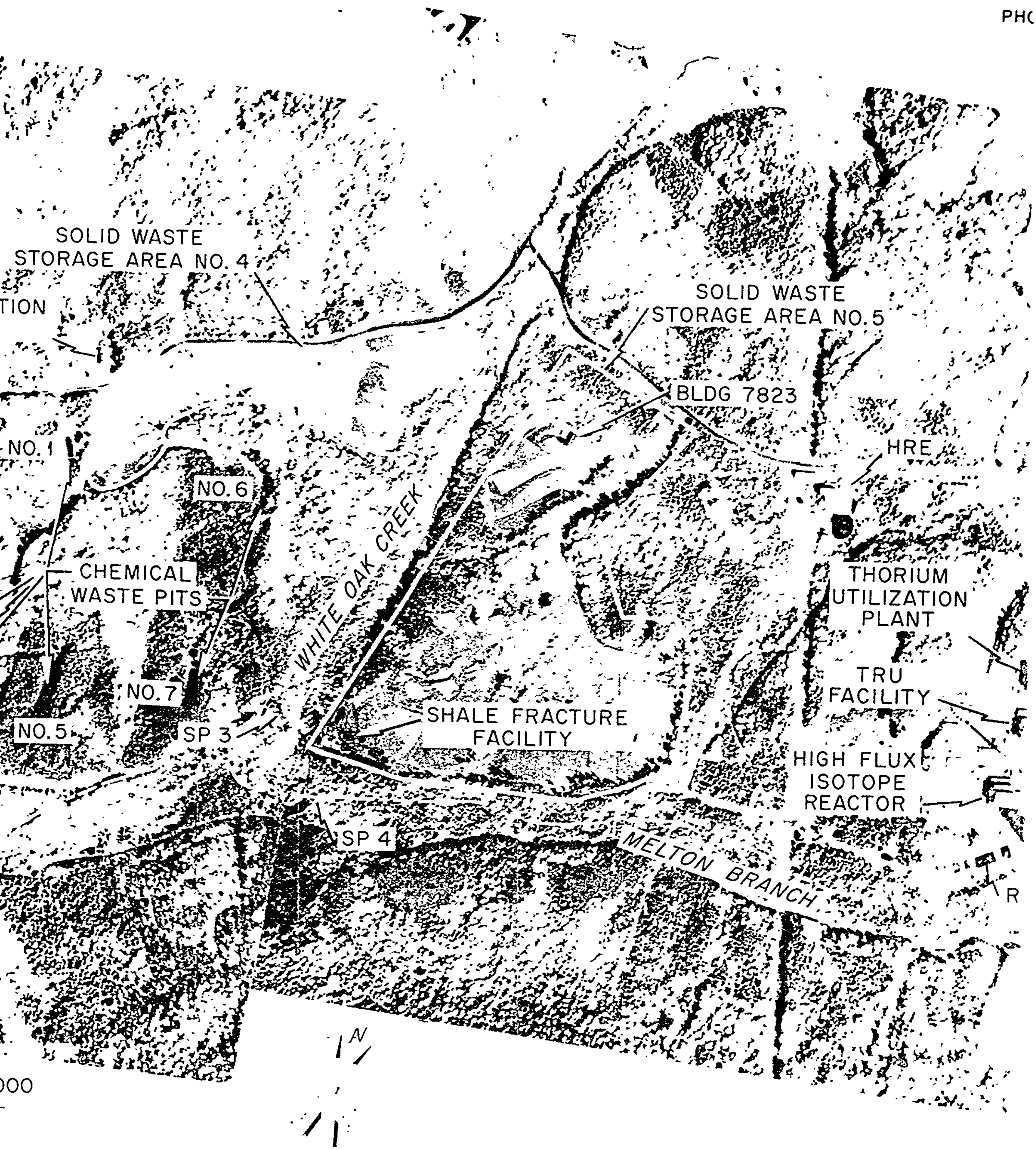

DECONTAMIN
BUILDIN
EMERGENCY WASTE BASIN
NO. 3
(ABANDONED)
NO. 2
(ABANDONED)
NO. 4
SOLID WASTE
STORAGE AREA NO. 6
SP 5
0
500
1000
1500
FEET

Fig. 26. ORN



-Melton Valley waste disposal facilities.

The following descriptions of the solid waste storage areas reflect an awareness of the problems associated with solid waste storage which has evolved over the years.

(a) Burial Grounds 1, 2, and 3. These areas are located in Bethel Valley at the main ORNL site. Burial grounds 1 and 2 are relatively small, covering a total of about 5 acres, and were closed by 1946. Wastes were merely dumped into the open trenches that were then backfilled. The locations of these burial grounds are shown in Figure 27, a photograph of the Clinton Laboratory (now ORNL) showing the two areas during the time they were in use. There are no available records showing the quantity or kind of solid waste disposed of in these areas; however, because of the close accountability exercised at that time and the extreme value placed on the material, very little fissionable material was disposed of in these areas. Moreover, large quantities of radioactive material had not yet become available so the amount of radioactivity present is also presumed to be small. These areas were used primarily for the disposal of contaminated trash, laboratory equipment, and other items that were discarded. The areas are now completely covered and no longer specifically fenced.

Burial ground 3 was opened in 1946 and used for underground disposal of waste, in much the same way as previous burial grounds, until it was closed in 1951. In addition, large items of equipment that were slightly contaminated and either too awkward to bury or salvageable, were stored within the fence around the area. The location of burial ground 3 can also be seen in Figure 27.

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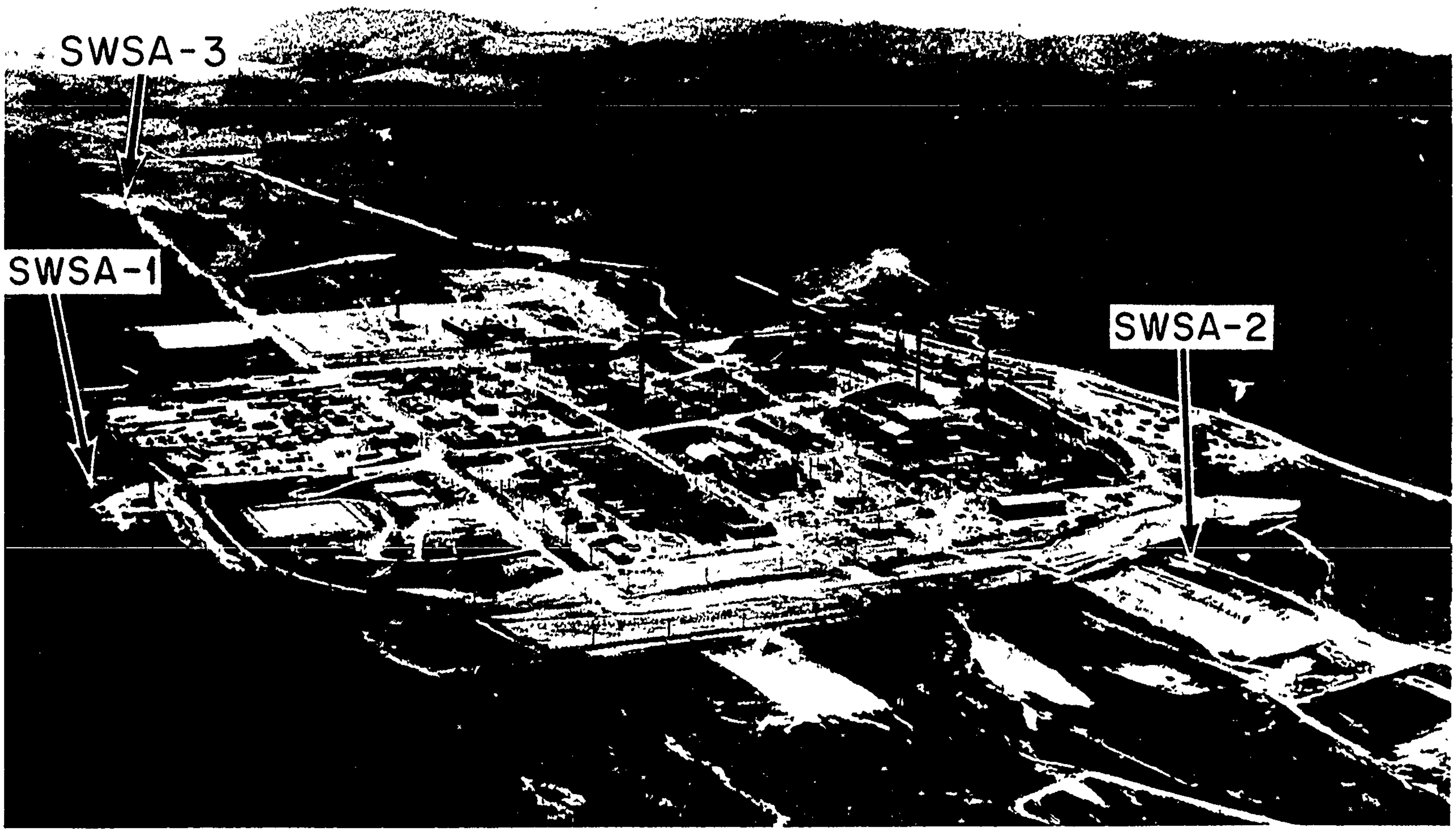


Fig. 27. Photograph of Clinton Laboratory (now ORNL).

After burial ground 3 was opened it was found to be underlain with rock difficult to excavate, and it was closed in 1951 after about seven acres had been utilized.

As in the case of previous burial grounds, little information is available on the volume, character, and location of the material buried in this area. Because burial ground 3 is still used for aboveground storage and is fenced.

(b) <u>Burial ground 4</u>. By 1951 studies on the movement of radioactive nuclides in soil determined that Conasauga Shale was ideal for the burial of radioactive wastes (Cowser and others, 1961). Consequently, the site for the new burial ground was chosen in Melton Valley, just southwest of ORNL.

As before, little was done with respect to exploration of the geologic and hydrologic aspects of the site beyond a determination that the area was indeed underlain by Conasauga Shale. As a result, portions of the surface of this area are uncomfortably close to the water table. Although the area is no longer in use, a study to determine what problems, if any, this situation may present is currently being conducted by members of the Environmental Sciences Division. Some of the results of this study will be presented in subsequent text.

Waste disposal in burial ground 4 began in 1951 and, as in the previous cases, all disposal was by burial. Attempts were made to segregate beta-gamma and alpha contaminated material; the latter, in some cases, was covered with concrete prior to backfilling. This area eventually covered a total of 23 acres; it was closed in 1959, seeded in grass, and fenced. Warning signs indicating the presence of radioactivity are posted in the area.

(c) Burial ground 5. As a result of experience gained in operating the previous burial grounds, greater care was taken in selecting the site for burial ground 5, which was opened in 1959. This previous experience (Cowser and others, 1961) led to the conclusions that (1) a burial site should be in an area of gentle relief for ease of operation and yet not be subject to flooding, (2) sufficient depth to ground water should be maintained so that contaminated solids can be suspended above the water table, and (3) the surface should not be subject to excessive soil erosion by surface runoff. Other desirable features of the site include (1) a soil that is easily excavated by earth-moving equipment and yet firm enough to stand in deep cuts, (2) a short hauling distance from the point of origin of the waste, (3) private roads to use for transporting, and (4) an easily accessible location.

As a result of geologic and hydrologic studies and application of the above criteria, the site shown in Figure 12 was selected for burial ground 5. A topographic map of the general area, showing the depth of the water table below the surface is on file.

Burial ground 5 has been used for the disposal of all types of wastes described in Section II.A.2.; however, by far the largest volume of material is general radioactive waste which has been buried in trenches in "semi-retrievable" form. All of the "retrievable" material is located in this area, including the material stored aboveground.

Land usage of this area since 1961 is indicated in Table 5. The appreciable decline in volume by FY 1963 is caused by the discontinuance of this site as the Southern Regional Storage Area. The current projection for the next ten-year period is 125,000 ft^3/year or less.

Table 5. Burial Ground 5 Land Used and Waste Volumes

	Land Used (acres)	Total Volume	Volume Generated on-area (ft^3)	Volume Received from off-area (ft^3)
1976	0.8	98,498	97,912	586
1975	0.6	112,904	104,204	8,700
1974	0.6	124,331	124,313	18
1973[a]	0.5	112,158	112,138	20
1972	0.6	122,261	113,026	9,235
1971	0.8	134,319	126,652	7,667
1970	0.8	163,176	157,033	6,143
1969[b]	0.9	169,361	151,210	18,151
1968	2.2	242,079	220,371	21,708
1967	1.1	198,811	170,770	28,041
1966	1.3	159,001	132,606	26,395
1965	1.8	188,534	152,791	35,743
1964	1.5	321,147	121,925	199,222
1963	1.5	332,975	117,470	215,505
1962	2.4	424,650	236,958	187,692
1961	3.0	530,704	244,000	286,704

[a]Changed from Calendar year to fiscal in 1973.

[b]Changes from fiscal year to calendar year in 1969.

The volume of waste stored per acre is dependent upon terrain features and water table depth. Waste burials have varied from 100,000 ft^3 per acre to 220,000 ft^3 per acre. More than 96% of the volume is slightly radioactive material which does not differ from the material buried during the past three decades, and consists of a heterogeneous mass of absorbent paper, all types of glassware, scrap metal, dirt, various filter media, lumber, powder, wire piping, depleted uranium, animal carcasses from biological experiments, and experimental equipment that could not be economically decontaminated.

A general layout of burial ground 5 showing the locations of the various disposal facilities, is given by Webster (1976).

(d) Burial Ground 6. In anticipation of future needs, the 68-acre site was opened in 1969; its location is shown in Figure 26. The criteria used to select this site were quite similar to those used in the selection of burial ground 5. Topographic and water-table conditions of burial ground 6 are shown in Figure 28.

This area is now being used for semi-retrievable storage in trenches and auger holes following practices identical to those currently in use at burial ground 5. The location and alignment of trenches and location of wells in this area are shown in Webster (1976).

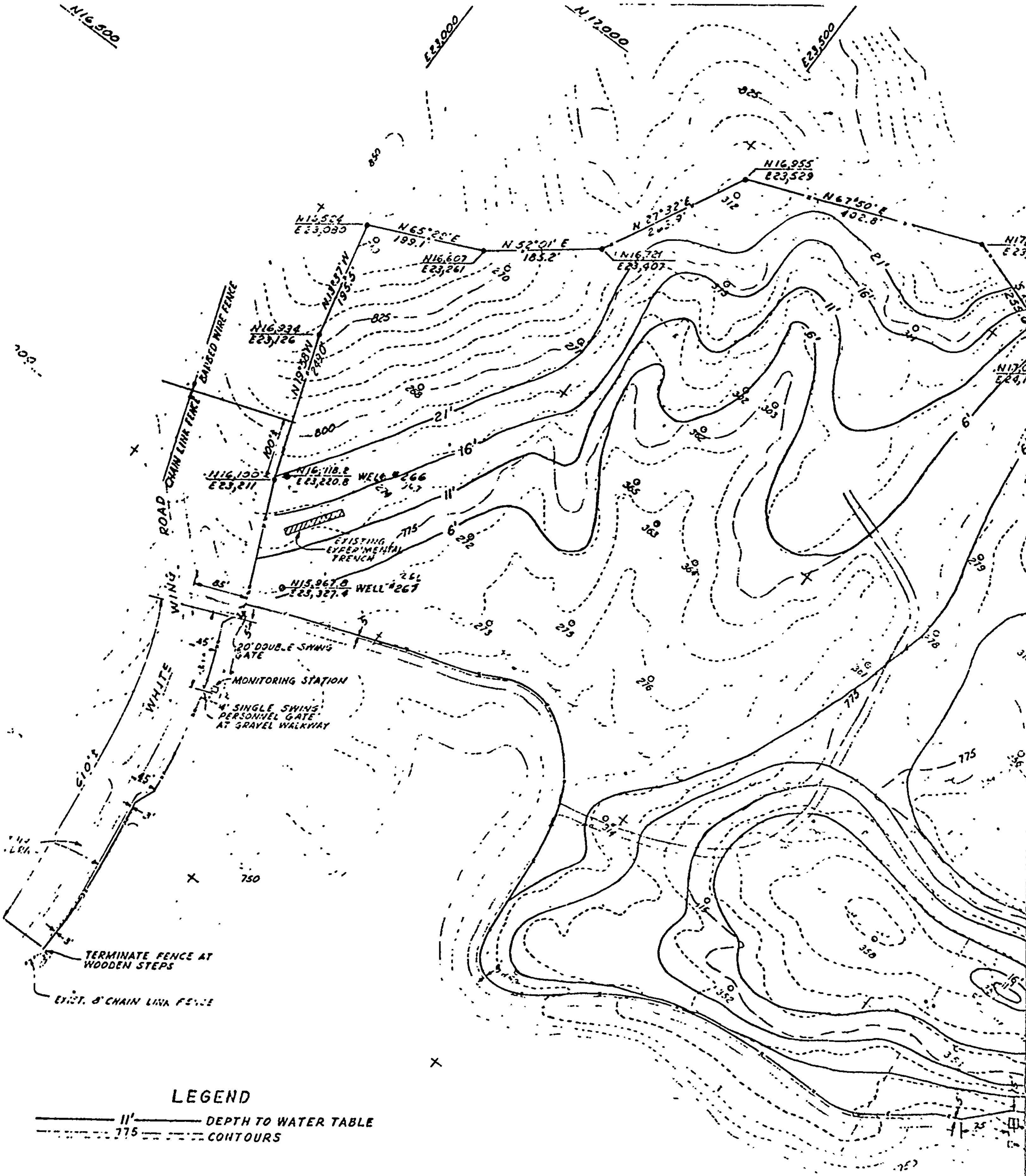
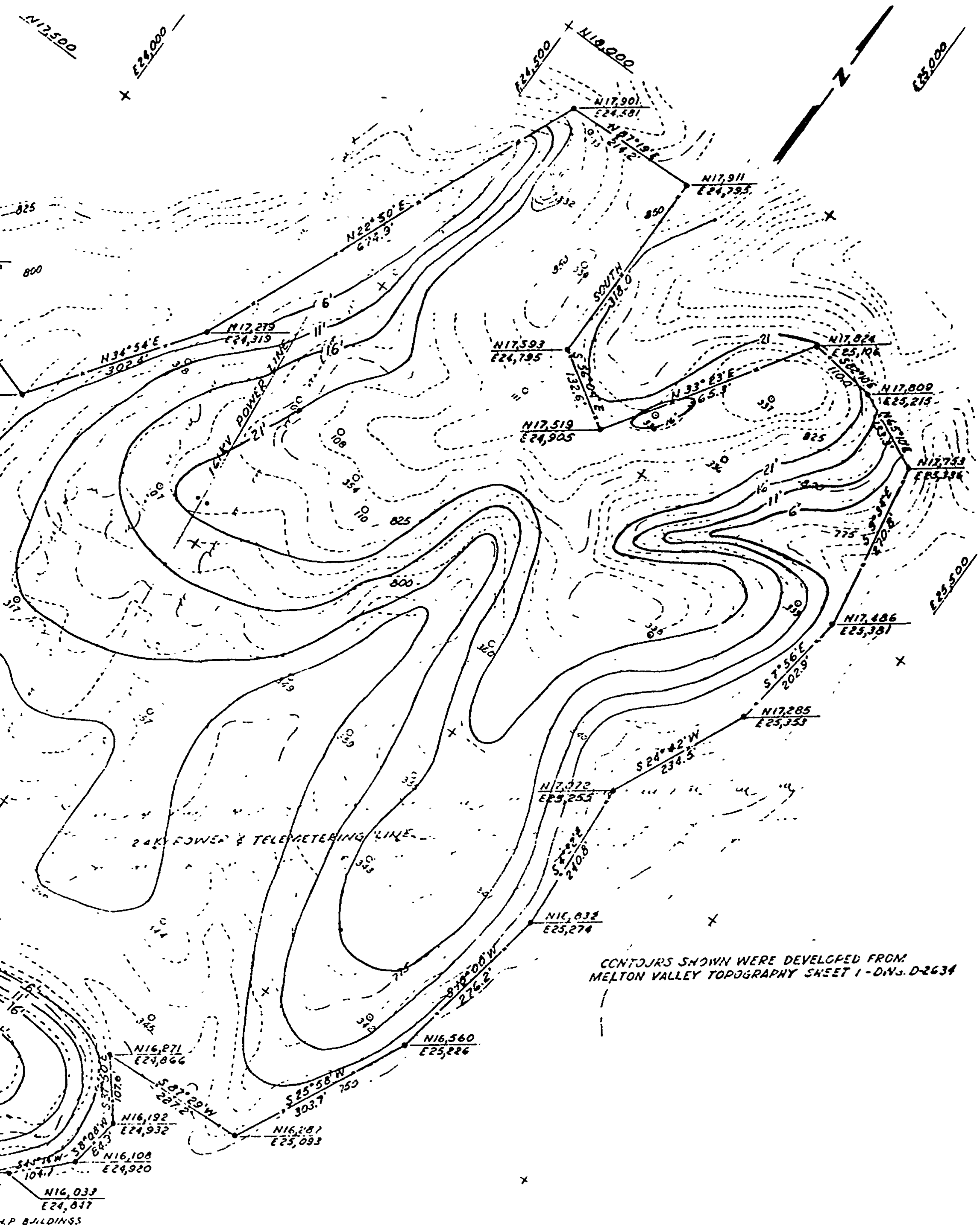


Fig. 28. Water tabl


N12500
E24,000
N18,000
E24,500
E25,000
E25,500
N17,901
E24,581
N17,911
E24,795
N22°50'E
614.9
SOUTH
318.0
N17,279
E24,319
N34°54'E
302.4
14 KV POWER LINE
N17,593
E24,795
N17,519
E24,905
N33°E3'E
N17,824
E25,106
N17,809
E25,215
N17,753
E25,336
N17,486
E25,381
S7°56'E
202.9'
N17,285
E25,353
S24°42'W
234.5'
E25,255
24 KV POWER & TELEMETERING LINE
N16,832
E25,274
S10°00'W
276.2'
N16,560
E25,226
S25°58'W
303.7'
N16,281
E25,093
N16,871
E24,866
S87°29'W
227.2'
N16,192
E24,932
N16,108
E24,920
N16,033
E24,877
CONTOURS SHOWN WERE DEVELOPED FROM
MELTON VALLEY TOPOGRAPHY SHEET 1 - DWG. D-2634
825
800
775
850

at SWSA-6.

II. FACILITIES

B. Assessment

1. Introduction

The potential hazards that accompany burial practices fall into two general categories: hazards to the personnel engaged in the operations, hereinafter called "operational hazards"; and potential hazards to the general public, which for convenience are designated as "environmental hazards". Operational hazards include the ordinary industrial safety hazards that accompany any excavation, hauling, or lifting operation and also contamination, radiation, and criticality hazards that may arise because of the peculiar nature of the material being handled. These hazards and the precautionary policies and procedures established to minimize them will be discussed in Part III of this report.

Environmental hazards are due almost exclusively to the radioactive or fissile nature of the waste, but in rare instances, could be caused by ground burial of nonradioactive chemical wastes. In nearly all cases, the wastes are "passive" in the sense that the toxic material stored does not possess a high potential for rapid energy release. This fact constitutes an important distinction between the hazards associated with a chemical reprocessing plant or a nuclear reactor and those associated with radioactive waste storage and disposal.

The real or potential environmental hazard associated with waste storage and burial operations can be traced to essentially three primary sources. These are a) improper handling of waste materials resulting in accidental spills or releases or some other related event caused by human error or equipment failure; b) the occurrence of a natural disaster which could damage or destroy storage facilities and expose wastes to the environment; and c) incomplete isolation and containment by storage and burial facilities resulting in ground water contamination and transport to the ground surface. Clearly the first of these relates solely to operating practices (see Part III), whereas the second involves the adequacy of the design, construction, and location of facilities. However ground water seepage problems are much more complex and can result from inadequate facilities, poor operating practice, or both. For the purpose of this report, seepage problems will be considered in the assessment of facilities and remedial actions taken to correct these problems will be considered in the section assessing operating practices.

2. Natural Disasters

Potential spontaneous causes of significant environmental hazard are from naturally occurring events such as fires, floods, tornadoes, or earthquakes.

(a) Fire

Much of the waste stored by burial below grade consists of wood, paper, cloth, and other combustible materials. Once the storage trenches have been backfilled, these materials no longer present a fire hazard; however, during the period when the trench is in active use prior to backfilling, a fire hazard does exist, and care is taken to prevent ignition of the material. The ordinary precautions associated with operation within a contamination zone are sufficient to reduce the hazard of fire to an acceptable level.

In the past, a few instances of either combustion or rapid oxidation of waste have occurred as a result of inadvertent mixture of the waste with strong oxidizing agents such as nitric acid. This interaction is accompanied by the emission of fumes from the trench, but is readily extinguished by immediate backfilling of the area involved. Consideration is being given to methods of preventing such occurrences.

The material stored in a retrievable fashion in auger holes or aboveground is essentially noncombustible.

One other source of hazard is the occasional storage of pyrophoric materials such as relatively finely divided metals, particularly such metals as zirconium and magnesium. Under certain conditions, these metals are known to undergo rapid spontaneous oxidation that can result in the rapid release of substantial quantities of energy. Handling of such materials is rare; but when necessary, they are packaged in containers approved individually by both the ORNL Fire and Safety Departments, handled as a special individual shipment, and stored in a section of the burial grounds sufficiently far removed from all other material so that there is no possibility of interaction. Such materials are covered with earth immediately after they are placed in the trench.

Uranium and plutonium metal are also pyrophoric; however, they are virtually never disposed of in the burial grounds. Any necessity for such disposal would require special approval by the appropriate committees.

As pointed out previously, the disposal of alkali metals by burial has largely been discontinued; however, should such burial become necessary, precautions similar to those described above would be taken.

The Laboratory has a resident fire department on duty 24 hr/day, trained to handle the type of emergencies that could arise and adequate to handle any foreseeable situation.

(b) Floods

Based on data supplied by the Tennessee Valley Authority, the maximum probable flood in the area in which the waste disposal facilities are located could reach an elevation of 768.5 ft, which is below the minimum elevation of the bottom of the lowest trench. Thus, a flood would not be expected to directly affect the disposal facilities. The precipitation necessary to cause such a flood would, however, aggravate the seepage problem considerably.

(c) Tornadoes

Below-ground storage, once backfilled, is essentially invulnerable to high winds, even those with tornado force. The same is true of the material stored in auger holes.

The greatest hazard that could result from a tornado would be a funnel passing directly across an open trench that had not yet been backfilled. In this circumstance, some contaminated material could be scattered over a considerable area; however, the likelihood of this is small.

The only other facilities vulnerable to tornadoes (aside from office buildings) are the retrievable waste storage buildings (7823 and 7826). Building 7823 is protected because most of the structure is placed below grade, with only the overhanging saddle roof exposed. A tornado would undoubtedly remove this roof, either in whole or in part, because of its aerodynamic properties, and deposit it in some nearby area. The steel structure of the building, because of its anchorage below grade, would remain intact. This remaining structure and the below-grade position of the stored drums offer protection from vortex-induced forces similar to that provided by western prairie storm cellars. Scattering of the drums within the shelter would take place, and conceivably some drums might be ruptured by impact with the steel structure or the side walls of the below-grade shelter. Because of the presence of the steel fencing located under the roof, as a ceiling, and the fact that the drums are palletized, the drums would probably not be transported outside the building.

Building 7823 is now used primarily as a staging area for Building 7826. Since 1976 when the latter was constructed and occupied, the former has no longer served as the principal storage facility.

The new Retrievable Waste Storage Facility, Building 7826 has been designed for resistance to the ERDA Design Basis Tornado (DBT) to the following extent:

1) The building walls are protected from wind loading by earth backfill to a sufficient height to withstand DBT wind loading.

2) In the event of a "hit" by a DBT with 360 mph winds and ±3 psi pressure differentials, a high percentage of the roof panels would probably be removed either by wind loading or by pressure differential. However, analyses indicate that the roof framing structure would remain intact and would provide a barrier for stored drums that might tend to

be ejected into the air stream. The top and bottom purlins are staggered to provide a minimum clear space between roof framing members of less than 2 ft. Since the drums are 25 in in diameter, a purlin spacing of 2 ft would not allow free passage of an ejected drum. The probability of a drum becoming airborne is reasoned to be extremely remote.

3) In a recent study undertaken for the purpose of determining tornado risks and design wind speeds in the Oak Ridge area, J. R. McDonald has concluded that the probability of wind speeds exceeding those of the DBT is about 3×10^{-7} per year and that the probability of wind speeds exceeding 130 mph is about the same as the tornado frequency calculated above using Thom's method (Thom, 1963). It would appear, therefore, that the building is completely adequate to protect against the effects of wind and pressure.

The only credible occurrence that could cause the release of any of the contaminated material from the new Retrievable Waste Storage Facility would be penetration of the roof by a missile having sufficient kinetic energy to rupture one or more of the drums and subsequent entrainment of some of the contaminated material in the air stream.

The total quantity of fissile-alpha material contained in these drums is less than 4 kg or an average of about 6 g per drum. In general, the material in the drums consists of contaminated trash, such as paper, glassware, rubber, plastic, etc., so the material released would not form an aerosol and hence could not become an inhalation hazard. Moreover, because of the low level of activity present, it would not likely become a direct radiation hazard. On the other hand, the random dispersal downwind of small quantities of contaminated trash could pose a contamination hazard that, while not widespread, would be difficult to locate and clean up.

Because of the random and unpredictable nature of tornadoes and other violent storms, making a rational quantitative prediction of the area over which the contaminated material would be dispersed is impossible. However, because of the nature of the terrain and the fact that in most cases tornadoes move from southwest to northeast, the debris would probably be carried northeast along either Bethel or Melton Valley. In this direction, the distance from the facility of the nearest populated area is more than 7 km.

The foregoing conclusions apply also to Building (7823) with a somewhat higher probability of occurrence; however, as has been pointed out above, the use of Building 7823 for long-term storage has been discontinued with the completion of the new structure.

(d) Earthquakes

The only structures that could be involved in a significant way if an earthquake occurred are the retrievable waste storage building (Building 7826) and the staging building, 7823. Conceivably, the buildings could collapse, the drums could be scattered within the buildings and a few might open and spill their contents. However, this would only present a local contamination problem that the Laboratory emergency organizations are well experienced in handling.

An earthquake by itself would have no significant effect on underground conditions, although horizontal displacements could conceivably do considerable damage to the auger holes and make retrieval of the waste difficult.

For important changes to take place, faulting would have to occur. Faulting that accompanies a truly major earthquake may involve large vertical or lateral displacements. In hard brittle rock, large faults of this type may shatter the rock along the fault plane and make a highly permeable pathway. In soft rock such as shale, the rock along the fault is ground to powder, and the fault trace is impermeable. The trace of the Copper Creek thrust fault, which is about 230 million years old, was intersected at a depth of 1360 ft during a drilling operation. The fault plane was represented by 2 to 3 ft of finely crushed shale, quite impermeable, and showed by the lack of alteration or the deposition of any minerals such as calcite that no water had ever moved along it. Even an earthquake accompanied by faulting would thus be quite incapable of forming a permeable channel through the shale underlying the burial grounds. Therefore, a major earthquake would not cause the disposal facilities to become a serious environmental hazard; however, considerable cleanup and repair work might be required.

3. Environmental Monitoring System

In order to assess disposal facilities and practices and to evaluate any associated environmental hazards, an adequate environmental monitoring system is necessary. Such a system is currently in operation in White Oak Creek watershed; however, the adequacy of this system is questionable.

The present monitoring system consists of two components: 1) a number of wells of variable construction and state of repair in and around burial sites, and 2) five surface water monitoring stations located on White Oak Creek and its tributaries. Accurate and reliable data are required from each component because radionuclide migration from burial sites involves both subsurface and surface transport mechnisms.

(a) Subsurface monitoring

At the request of the Atomic Energy Commission (now ERDA), the U.S. Geological Survey conducted an independent evaluation of the ORNL burial facilities and practices. A recently published USGS report (Webster, 1976) reviews the history and geologic and hydrologic conditions related to the burial grounds and evaluates the monitoring system as it existed in 1974. This report indicates that two shallow wells were located immediately outside of the lower end of burial ground 1 (see Fig. 23) in 1973, but these were subsequently destroyed. No well data or records of previous investigations were reported for burial ground 2. On the other hand, each of the remaining burial sites was reported to have a network of wells capable of yielding water samples. A total of 12, 60, 30 and 47 wells were shown to be present in or adjacent to burial grounds 3, 4, 5, and 6 respectively (see Webster, 1976, Figs. 8, 10, 11, and 13). Even though a significant number of wells were present, they were not ideal for monitoring purposes. Most of the existing wells were, and continue to be, simply shallow auger holes with uncapped, corrugated casings perforated throughout their length. The well fields have not been maintained adequately and many wells have been destroyed or deteriorated to a point that they are no longer useful. These and other observations led Webster (1976, p. 3) to conclude that "Realistically, a monitoring system designed to maintain surveillance of radionuclide movement from the burial grounds simply does not exist", and that "... it is inadequate for monitoring radionuclide transport in ground water from the burial grounds or for providing information necessary to manage these areas for the long-term retention of their contaminants." Consequently, one of the specific recommendations stated in Webster's report is the development of an integrated ground water-surface water monitoring program. An obvious companion recommendation is an intense hydrogeologic investigation of the area to better define ground-water movement and the factors controlling such movement to insure proper location of monitoring wells.

To date, an adequate subsurface monitoring system still does not exist. However, studies are presently being conducted which will provide some of the necessary information for the design and implementation of such a system (D. A. Webster, U. S. Geological Survey, oral commun., 1977). Since the initial investigation was completed, 4 additional observation wells have been installed in burial ground 4, about 40 have been placed in burial ground 5, and approximately 18 have been added to burial ground 6. These wells are used to make water-table measurements and monitor fluctuations in its position. Personnel of the U. S. Geological Survey have geophysically logged selected wells in burial grounds 3, 5, and 6. Data obtained from this study will permit identification of γ-emitting radionuclides in the ground water as well as certain physical characteristics of the rock medium. Two tracer studies are currently underway to examine the rate and direction of ground-water movement at the base of the weathered zone. These tests, using tritiated water, are being conducted in burial ground 6 and on the hillslope above burial ground 4. In addition plans are made for a number of deeper, well constructed wells in the burial sites. These wells are planned to be located primarily in burial ground 5, but if sufficient money is available, additional installations will be made in burial ground 6. These wells will be up to 200 ft deep and grouped in clusters of 4(?). Cores will be obtained and analyzed in one well from each cluster. These wells will be open at various depth intervals and function as piezometers to obtain data on the pressure head distribution within the burial grounds. Finally, a rigorous water sampling and analysis program is planned to obtain a detailed data base on the radionuclide content of ground water in burial ground 5. After the results of these and related investigations are available, the proper design and installation of a subsurface monitoring system can begin.

(b) Surface monitoring

A network of five monitoring stations (Fig. 29) is presently in operation to monitor the radionuclide content of surface waters in the White Oak Creek watershed. Station 1 is located a short distance below Waste Pond No. 2 (process waste settling basin, Fig. 23) and monitors the effluent discharged from the settling basin and the waste-water treatment plant. Station 2, located on White Oak Creek a short distance upstream from Station 1, provides data on radionuclide content of the water upstream from the point of effluent discharge. Station 3, located on White Oak Creek a short distance above the confluence with Melton Branch, and Station 4, located at an analogous position on Melton Branch (Fig. 29), provide general information on the contaminant contribution

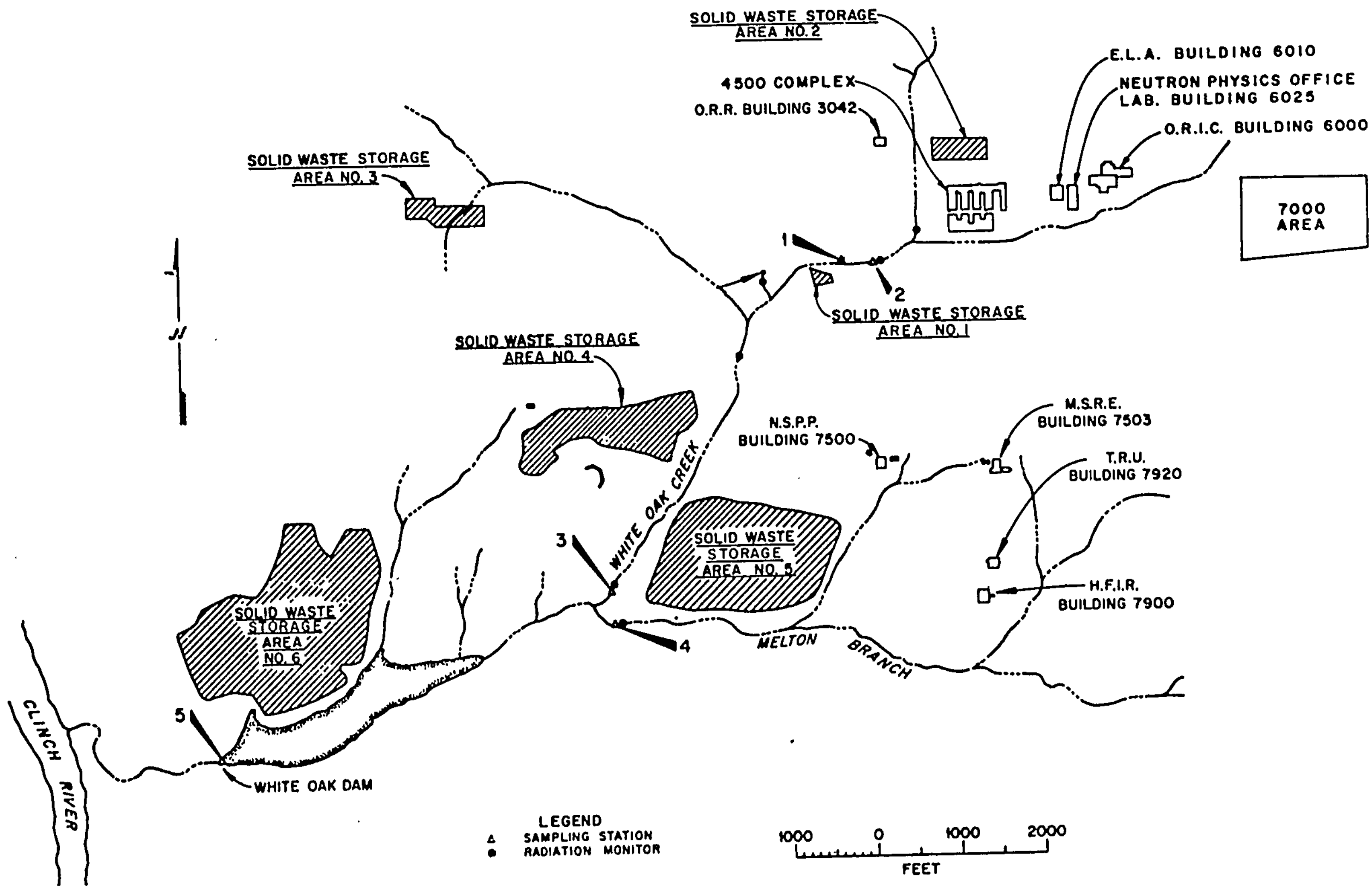


Fig. 29. Location plan of ORNL solid waste storage areas and monitoring stations.

from each valley. Station 5 at White Oak Dam provides data on radionuclide content of water leaving the watershed and entering the Clinch River.

Stations 1 and 2 continuously monitor beta and gamma activity in the streamflow. Flow-proportional samples are collected at station 2 and composited for monthly analysis. At stations 3 and 4, discharge is measured by Cipolletti weirs and water is pumped continuously through the system for counting (β and γ activity) and proportional sampling. Dissolved oxygen, temperature, and pH are also monitored. Composite samples are analyzed monthly for activity and strontium concentrations (see Webster, 1976). Samples are collected at station 5 by a continuous proportional sampler. Weekly composite samples are analyzed for gross beta activity, transuranic alpha emitters, total strontium, tritium, and iodine-131. Monthly composite samples are formed from portions of the weekly samples and these are analyzed for strontium-90, cesium-137, barium-140, cerium-144, ruthenium-106, zirconium-95, niobium-95, cobalt-60, tritium, plutonium, transplutonium, and gross beta (Oakes and others, in review). These samples are also analyzed for heavy metal content. Portions of these monthly samples are composited for quarterly analysis of all gamma-emitting radionuclides and transuranics, and as a check on the weekly analyses for strontium-90 and tritium (T. W. Oakes, ORNL, oral commun., 1977). As a check on the calculated concentrations leaving White Oak Creek watershed, two sampling stations are maintained below the entry point on the Clinch River: one at Clinch River Mile (CRM) 14.5 at the water intake for the Oak Ridge Gaseous Diffusion Plant and the other at Center's Ferry near Kingston, Tennessee (CRM 4.5). A sampling station is also maintained at Melton Hill Dam (CRM 23.1) above the confluence of White Oak Creek with Clinch River to provide baseline data. Samples are collected daily at each of these three stations and analyzed quarterly (Oakes and others, in review).

It would seem that the present surface monitoring system and associated sample collection and analysis program is more than adequate. However, this is questionable, particularly in terms of monitoring burial ground contribution to surface water contamination. Figure 29 indicates that station 3 on White Oak Creek above Melton Branch monitors drainage from burial grounds 1, 2, 3, 4, and portions of 5. Additionally all discharge from ORNL operations are included in this flow. Station 4 on Melton Branch monitors water from portions of burial ground 5, several reactor test sites, and other contaminated areas. At station 5, inputs to the entire watershed are monitored. Thus, with the present network, it is impossible to define the origin of all contaminants monitored at individual stations. By comparing data collected at the various sites, the radionuclide contribution from certain general areas can be determined; however, it is not possible to isolate the contribution from individual disposal sites with the present system.

An additional shortcoming of the surface monitoring system is the inability of the stations to measure flow through a wide range of discharges. The maximum measurable discharge at stations 3, 4, and 5 are approximately 50 cfs (ft^3/sec), 19 cfs, and 150 cfs respectively. When streamflow exceeds these values at the respective sites, no record of flow rate or volume is obtained; furthermore, proportionality of collected samples is lost. Although certain data indicate that, on the average, discharge exceeds measuring capacity at these stations for a small percentage of the time each year, abundant evidence indicates that a disproportionately large volume of water and sediment are transported during times of large discharge. Because radionuclides are transported in these waters and in association with sediment, no accurate records of contaminant transport and release are available for these periods. Interestingly, the discharge measuring capacity of the monitoring system has been exceeded on two separate occasions during the past six months for a total period of time of approximately 100 hours (T. W. Oakes, ORNL, oral commun., 1977). Additional problems and potential sources of error associated with the present monitoring and sampling system are noted by Webster (1976).

Three new monitoring stations have been designed and are to be installed in the very near future. It is planned to locate one station on White Oak Creek immediately above burial ground 4 (see Fig. 29), a second on Melton Branch above burial ground 5, and the third on the tributary to Melton Branch which flows past the eastern boundary of burial ground 5 (D. A. Webster, U. S. Geological Survey, oral commun., 1977). The addition of these new stations will enhance efforts to monitor radionuclide contribution from the various disposal and storage areas. In addition the possibility is being explored to increase the discharge measuring capacity of stations 3, 4, and 5 and to install more refined flow proportional sampling equipment at these same stations. However, a decision on this action has not been made at this time.

4. Seepage Problems

Currently, the only off-area environmental effect that can be attributed to waste disposal results from ground water seepage that carries dissolved or entrained radioactive material into White Oak Creek. The principal radionuclides involved are ^{3}H and ^{90}Sr.

Tritium has been observed at the mouth of White Oak Creek for many years. The annual quantities discharged to the creek since 1964 are shown in Table 6. Starting in 1967 there was a dramatic increase in the quantity delivered to the creek. This increase was investigated and the evidence indicated that the tritium originated in shipments of material received from Mound Laboratory prior to 1967. This waste material was disposed of in burial ground 5.

Table 6. Radioactivity discharges to White Oak Lake attributed to seepage from solid waste storage areas.

	Quantity (Ci/Year)	
Year	Tritium[a]	Strontium-90[b]
1964	1,930	3.36
1965	1,160	3.48
1966	3,100	1.92
1967	13,270	2.76
1968	9,690	1.92
1969	12,250	1.33
1970	9,470	1.35
1971	8,950	1.19
1972	10,600 (1060)[c]	1.97
1973	15,050 (760)[c]	2.19
1974	8,633	5.30
1975	11,060	3.70
1976	7,420	4.30

[a]Total entering White Oak Lake from all sources.

[b]Difference between sampling points 1 and 3.

[c]Numbers in parentheses represent contribution from main branch of White Oak Creek.

Recent investigation indicates that this is indeed the case. Samples taken in Melton Branch at sampling point 4 and at sampling point 2 on White Oak Creek indicate that 90 percent of the tritium is coming from Melton Branch (Fig. 29), and the quantity originating upstream from the junction of the two creeks is of about the same order of magnitude as that observed for the total prior to 1967. Thus, the bulk of ^{3}H entering White Oak Lake is discharged to Melton Branch from burial ground 5 with lesser amounts coming from other waste disposal areas (seepage pits and trenches and burial ground 4) in the drainage (Duguid, 1975).

Although rather large quantities of tritium are being discharged to the Clinch River, this problem is not regarded as acute at this time. Taking into consideration the mean river flow of 4200 cfs, a discharge of 1 Ci/year from White Oak Creek represents a mean concentration in the river of 2.67×10^{-10} μCi/ml. The most restrictive guideline value for tritium in water is 1.0×10^{-3} μCi/ml. Hence, an annual discharge of nearly 40,000 Ci/year would be required to produce a concentration in the river which exceeds one percent of the guidelines. As can be seen from Table 6, the current rate of discharge is well below this figure.

The difference between ^{90}Sr discharge at sampling points 1 and 3 can be attributed to ground-water discharges from burial ground 4 (Duguid, 1975). These discharges for the years 1964 through 1976 are shown in Table 6. The leaching and discharge is believed to be enhanced by high water table conditions in the burial ground (Duguid, 1975; Webster, 1976). A comparison of burial ground 4 with selected burial sites at SRP, INEL, HW, and LASL is given in Dames & Moore (1976). The

Dames & Moore study indicates that of the burial grounds studied, burial ground 4 had the greatest possibility for ground-water contamination.

Discharge data shown in Table 6 indicates that a good relationship exists between ^{90}Sr discharge and monthly creek flow (Fig. 30). The same data (only on a water year basis) shows a definite relationship between precipitation and ^{90}Sr discharge from burial ground 4. These data are given in Table 7 and are plotted in Figure 31.

Table 7. Discharge ^{90}Sr from burial ground 4 and precipitation data for water years 1963 through 1975.

Water[a] year	Precipitation (in)	Total ^{90}Sr discharge (Ci)	Discharge of ^{90}Sr (mCi/in)
1963	55.33	4.82	87.1
1964	42.09	2.71	64.4
1965	51.98	3.10	59.6
1966	40.85	2.52	61.7
1967	60.54	2.72	44.9
1968	45.01	2.04	45.3
1969	40.07	2.08	51.9
1970	47.93	1.60	33.4
1971	48.26	1.18	24.5
1972	47.40	2.36	49.8
1973	71.27	1.58	22.2
1974	68.76	5.22	75.9
1975	57.73	3.22	55.8

[a]Water year in September 1 through August 31.

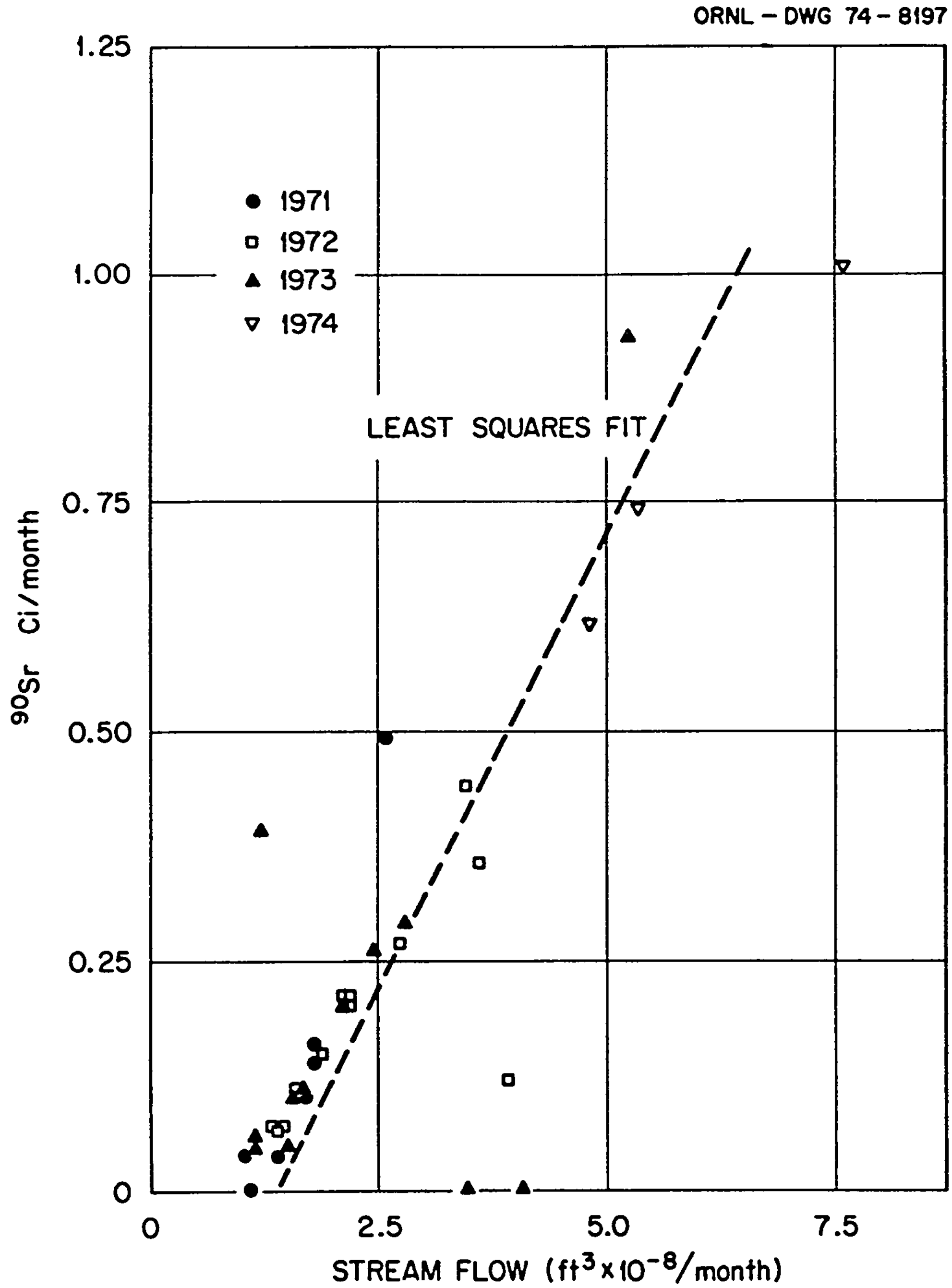


Fig. 30. Apparent ^{90}Sr concentration to White Oak Creek from SWSA-4 (June 1971-March 1974).

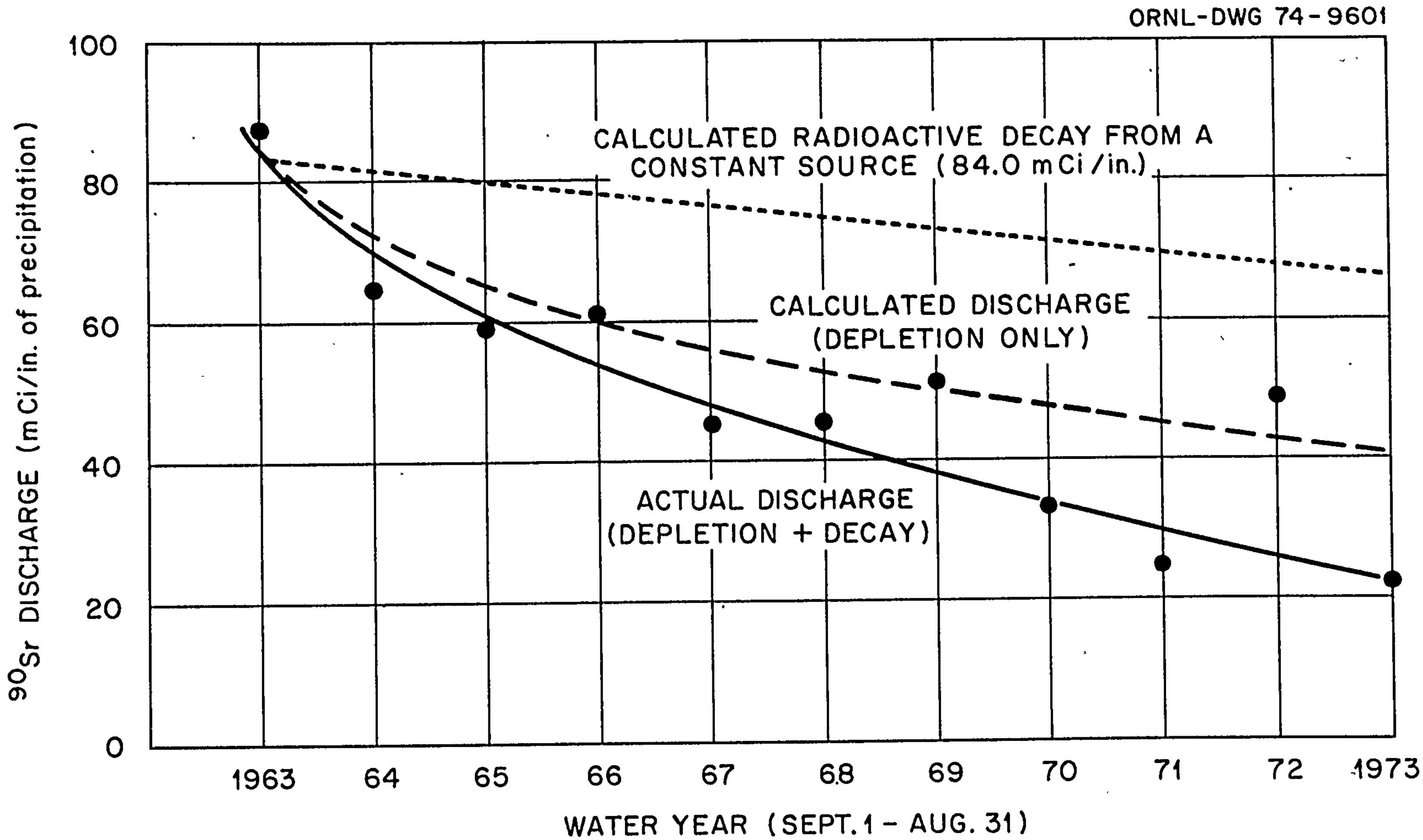


Fig. 31. Discharge of ^{90}Sr from burial ground 4 for water years (September 1 - August 31) 1965 through 1973, in mCi/in. of precipitation (from stream monitoring data).

The plot shows that ^{90}Sr discharge is decreasing from both radioactive decay and depletion of the buried waste by leaching. The data also suggest a strong relationship between total discharge and the amount of precipitation. This observation has been substantiated through studies of ^{90}Sr sorption and leaching using soils collected below burial ground 4. Thus, the primary methods of controlling ^{90}Sr discharge from the burial ground must rely on reduction of water passing through the buried waste. This reduction can be achieved through near-surface sealing of the area, which will provide a barrier to infiltrating precipitation.

The discharge of ^{90}Sr from burial ground 5 is monitored at sampling station 4 on Melton Branch (Fig. 29). The bulk of the ^{90}Sr passing this point (> 90%) is estimated to come from the burial ground, while < 10% is estimated to come from the HRT settling basin and the contaminated area below it. The ^{90}Sr discharge from burial ground 5 for the water years 1967 through 1976 is given in Table 8. The highest

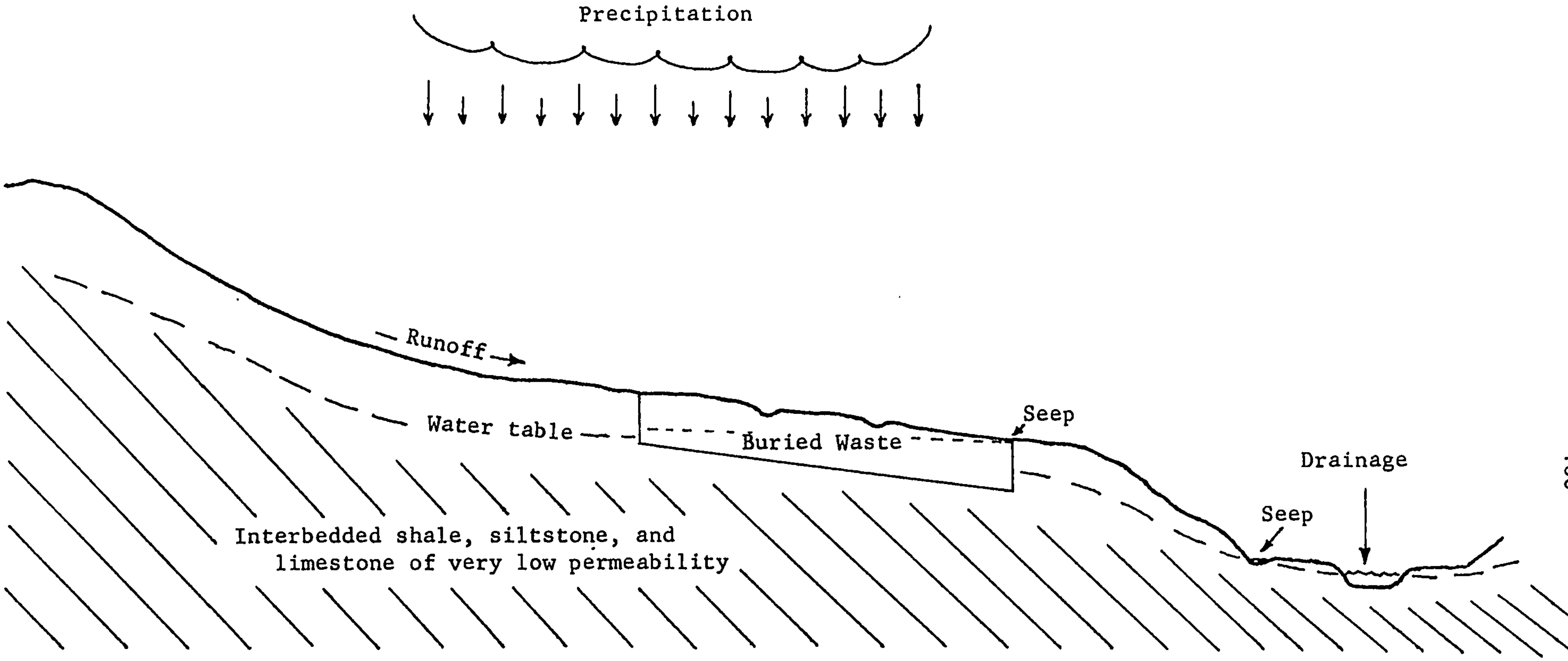
Table 8. Discharge of ^{90}Sr from burial ground 5 and precipitation data for water years 1967 through 1976.

Water[a] year	Precipitation (in)	Total ^{90}Sr Discharge (Ci)	Discharge of ^{90}Sr year (mCi/in)
1967	60.54	0.89	14.7
1968	45.01	2.84	63.1
1969	40.07	0.88	22.0
1970	47.93	0.93	19.4
1971	48.26	0.58	12.0
1972	47.40	0.81	17.1
1973	71.27	1.43	20.1
1974	68.76	1.39	20.2
1975	57.73	2.07	35.9
1976	51.18	0.75	14.7

[a]Water year is September 1 through August 31.

discharge (1968) originated from a source other than buried waste. These data do not demonstrate the uniformity in discharge that was observed at burial ground 4. It is believed that the difference in the discharges from the two burial grounds arises from the time that has lapsed since completion of burial. Burial ground 5 has not yet begun to discharge ^{90}Sr uniformly, while burial ground 4 has been demonstrating uniform discharge since 1963 (and perhaps earlier). From burial ground 5, the discharge currently arises from trench overflow during the wetter winter months. The mechanisms leading to trench overflow are shown in Figure 32 (after Webster, 1976). Figure 32 also lists the major factors contributing to burial ground problems at ORNL.

In addition to ^{90}Sr discharges from burial sites, other radionuclides are known to be in the ground water and migrate to the surface environment. Webster (1976, p. 38-39) reported that alpha and beta activity were observed in water collected in 1959 and 1960 from two seeps in burial ground 4 and in the intermittent stream bordering the site on the south. An analysis of seep water indicated ^{90}Sr, ^{137}Cs, ^{95}Zr-^{95}Nb, ^{60}Co, and TRE were present; and ^{106}Ru, ^{90}Sr, ^{210}Po, $^{239,240}Pu$, and TRE were found in the stream samples. Well and seep samples collected in 1973 indicated the presence of ^{90}Sr, ^{125}Sb, ^{95}Zr-^{95}Nb, ^{137}Cs, and ^{60}Co. Webster (1976, p. 45-46) also reported analytical results for soil and water samples collected in burial ground 5. Analysis of surface and subsurface water samples in 1964 indicated that $^{89,90}Sr$, ^{106}Ru, ^{3}H, and trivalent rare earths were the principal contaminants. At about the same time, ^{106}Ru, ^{137}Cs, and ^{60}Co were found in cores obtained from several new wells. In 1974, seeps and surface drainage contained primarily ^{90}Sr, ^{3}H, ^{125}Sb, and ^{244}Cm.



FACTORS CONTRIBUTING TO BURIAL-GROUND PROBLEMS AT OAK RIDGE

1. Large amount of annual precipitation
2. Shallow depth to ground water
3. Residuum of very low permeability
4. Drainages within a few hundred feet of burial-ground boundaries

Fig. 32. Mechanisms contributing to radionuclide discharge from buried waste at ORNL.

The radioactive discharges from the seepage pits and trenches are small enough that they comprise a negligible fraction of the total discharge at White Oak Dam. The radionuclides contained in ground-water discharges from the seepage pits and trenches are ^{106}Ru, ^{125}Sb, and ^{60}Co (Duguid, 1975). Tritium is also present in ground water near these disposal areas (Duguid, 1976). The ^{60}Co found in the ground water is complexed with EDTA (Jeff Means, Princeton University, personal commun., 1977). This complexing agent is responsible for mobilization of ^{60}Co in the vicinity of the pits and trenches and may be responsible for mobilization of other radionuclides as well.

5. Adequacy of Existing Facilities

Adequacy, by definition, carries the connotation of being "able to satisfy a requirement". It seems that the basic requirement of burial facilities should be to contain the waste until it decays to the point that it no longer presents an environmental hazard. In this context, the ORNL burial facilities must be viewed as inadequate. Because of their engineering design, construction, location, and certain waste segregation procedures, present facilities appear to be adequate to contain wastes and inhibit dispersal by natural phenomena such as fires, floods, tornadoes, and earthquakes (see Section II. B. 2.). However, the present facilities are not capable of isolating buried waste from circulating ground water as evidenced by the seepage problems discussed in the previous section.

Burial grounds 1 and 2 are not known to have had serious seepage problems in the past or at present. However because very little is known of the type of waste buried in these sites and the lack of monitoring data, it cannot be demonstrated absolutely that seepage has not occurred. Under present conditions, burial grounds 3, 4, and 5 are clearly incapable of retaining all radionuclides, even for a relatively short period of time. Contaminants have been detected in the ground water at each of these sites and in adjacent surface waters as well. Because burial ground 6 has many site characteristics in common with burial grounds 4 and 5, the potential exists for analogous seepage problems to develop with time unless preventive measures are taken. It should be noted however, that due to the slow rate of ground-water movement, the high sorptive capacity of the geologic medium for the radionuclides concerned, dilution capacity of the surface waters, and other factors, it is very unlikely that large quantities of radionuclides have been released at any given time or that a serious public health hazard exists. Monitoring data at White Oak Dam supports this reasoning.

Webster (1976, p. 69) concluded that "... with the hydrogeologic conditions that prevail at Oak Ridge, neither the trenches nor the surrounding earth retain all radionuclides permanently." He further stated that "Thus, neither the early concept of safe and permanent retention of all radionuclides in trenches at Oak Ridge nor the later concept of retention in the geologic environment is valid." One of the principles for the burial of solid wastes contaminated with radioactivity recommended by the Panel on Land Burial, Committee on Radioactive Waste Management of the National Research Council (1975, p. 11) is as follows:

"The Panel believes that the major goals of a permanent low-level solid waste burial operation are to contain the waste until it decays to an innocuous level, to guarantee that the radioactive waste is under control at all times, and to guarantee that if contaminants migrate from the site, their movements can be predicted so that necessary corrective actions can be taken ...."

To fullfill these objectives, a site should have burial facilities that adequately isolate the wastes and inhibit ground-water intrusion, the hydrogeologic conditions of the site should be well understood, contingency plans and corrective measures should be formulated and capable of being quickly implemented, and a complete and reliable monitoring system should be in operation. Thus, when compared to these and similar criteria, the present ORNL burial facilities must be considered inadequate. However, with continued study and implementation of planned corrective measures and monitoring activities, this situation can be improved considerably.

III. OPERATING PRACTICES

A. Description

1. Introduction

The responsibility for the operation and maintenance of the facilities for the disposal and storage of solid radioactive waste at the Oak Ridge National Laboratory was assumed by the Operations Division in July, 1973. Direct responsibility is vested in the Hot Cells and Solid Waste Storage Operations Department, with technical staff assistance being available from the Development and Technical Assistance Departments of that Division.

Close liaison is maintained with the Radiation and Safety Surveys Section of the Industrial Safety and Applied Health Physics Division and with the Plant and Equipment Division. The former provides health physics surveillance for operations, and the latter supplies craft personnel, heavy equipment operators, truck drivers, laborers, etc., who perform the actual work.

Close liaison is also maintained with the Environmental Sciences Division. This division provides hydrological and geological consultant services for Solid Waste Management Operations and conducts research relating to environmental considerations of waste management practices.

2. Operational Supervision and Management

In addition to the direct supervision provided by the Operations Division, the solid waste storage operations is under the surveillance of three of the Laboratory Director's Review Committees.

(a) Criticality Committee - The Criticality Committee has review and approval jurisdiction over operations that involve the handling, storage, transportation, and disposal of significant quantities of fissile material. The fissile materials include the isotopes ^{235}U, ^{233}U, ^{239}Pu and the combined elements americium and curium. Approval of operations involving masses of the above materials in excess of established waste disposal limits must be obtained in advance on a nuclear safety review form submitted to the Committee. This form is initiated by the requester of the operation, approved by his Division Safety and Radiation Control Officer, and approved for a limited period of time by the Committee.

The Committee acts in many respects as a consulting group and gives assistance in problems involving criticality. It also conducts an annual review of each facility or balance area possessing significant amounts of fissile material to ensure the approval procedures are being followed.

Disposal of fissile material must be in accordance with the procedures in the ORNL Health Physics Manual with the approval of the Committee.

(b) Radioactive Operations Committee - The Radioactive Operations Committee reviews Laboratory facilities handling or processing significant quantities of radioactive materials and the practices used in disposal of solid, liquid, and gaseous radioactive waste. The Committee is particularly concerned with proper containment, complete and accurate operators' safety analyses, detailed operating procedures, and possible interactions (chemical, mechanical, or procedural) that might lead to unplanned exposure or contamination.

All new radiochemical facilities or processes are reviewed prior to operation; existing facilities are reviewed whenever changes in purpose or scope are proposed. The more important facilities are reviewed by the full Committee at intervals of one to three years, even though no changes in purpose or scope have been made or requested. Frequency is dependent on the magnitude of the operation and the hazard involved.

(c) Transportation Committee - The Transportation Committee is an ORNL standing committee appointed by and reporting to the Director. Serving on the Committee are specialists in the fields of stress analysis, inspection techniques, shielding, heat transfer, criticality, and transportation regulations. The Committee, on its own initiative or at the request of ORNL management, reviews all safety aspects of any phase of operations involved in the transfer of radioactive or fissile materials from one ORNL facility to another or one ORNL group to another, as well as shipments made offsite from ORNL. The Committee reviews casks used for intra-Laboratory transportation, and also such details of shipments as tie-down practices, vehicles used for transport of casks, inspection procedures, loading and unloading procedures, and any other procedures necessary for the safe transportation of radioactive materials.

The Committee also reviews accidents or incidents involving transportation of radioactive materials when they feel such reviews might provide useful information.

The conclusions and recommendations of these committees are summarized in reports to the Laboratory Director and to the appropriate Laboratory Division concerned.

Other groups within ORNL as well as others within the Operations Division also contribute to the solid waste storage and disposal effort of the Laboratory.

Within the Operations Division:

(d) The Isotope Sales Office

This office supervises off-site waste shipments and provides liaison between off-site shippers, ERDA reviewing office, and SWS area management.

(e) The Source and Special Materials Management Office

This office maintains the record file for ORNL of all transfers and inventories of special nuclear and source material.

(f) The Division Quality Assurance Coordinator

The Quality Assurance Coordinator represents the Quality Assurance Director and provides guidance and review on Quality Assurance activities when necessary.

(g) The Division Safety and Radiation Control Officer

This individual represents the division director in matters of radiation and industrial safety, discharging at the divisional level the responsibilities which are designated by the division director.

Within the Laboratory:

(h) The Office of Laboratory and Personnel Protection

This office represents the Director's Division in matters of industrial and radiation safety.

(i) The ORNL Representative of the UCC-ND Environmental Committee

This representative provides liaison between the committee and ORNL on matters of environmental pollution safeguard.

(j) The Industrial Hygiene Department

This department provides consultation on matters of industrial hygiene, particularly those relating to the prevention of ingestion and inhalation of hazardous materials.

(k) The Department of Quality Assurance and Inspection

In addition to guidance and review on QA activities when necessary, this department provides mandatory routine inspections and any physical inspections deemed necessary by SWS supervision.

(l) The Environmental Sciences Division

The ESD cooperates with and provides expertise to the groups directly responsible for maintaining the environmental monitoring program for the Laboratory. This Division also provides consultation services to those responsible for Solid Waste Management Operations on an as needed basis. A hydrological/geological review of trench location and design is performed at least annually.

(m) The Industrial Safety and Applied Health Physics Division

This Division furnishes the expertise to deal with personnel radiation exposure control through its assigned surveyor. This organization also measures and evaluates situations involving radioactive contamination and administers a portion of the environmental monitoring program.

3. Waste Handling

(a) General

Waste at ORNL is handled in accordance with the intent of UCN Standard Practice Procedure D-5-15. The initial handling and packaging of radioactive wastes at the point of origin is governed by two requirements: first, to protect personnel from exposure to radiation and contamination, and second, to ensure that the various classes of materials are placed in containers of a kind appropriate for the type of storage prescribed.

In order to protect personnel against radiation and contamination, waste containers in current use in operating areas should have a low radiation intensity at the surface and be essentially free of transferable contamination. Appropriate precautions have been established and are presented in the ORNL Health Physics Manual.

Various types of containers are designed as "approved" containers for the different classes of solid radioactive waste. These are designed to provide adequate shielding where necessary, to be suitable for transport to the solid waste storage areas, and to be appropriate for the type of storage contemplated.

For the purpose of handling at the point of origin, low-level general radwaste may be conveniently thought of in terms of very low level material that requires little in the way of special precautions but material that is sufficiently radioactive to require precautions as described in ORNL Health Physics Manual, Procedure 2.7.

The methods utilized to transport solid waste from its point of origin to the burial grounds varies according to the character of the waste and the type of package involved. By far, the greatest volume of waste is handled in dumpsters or packaged in garbage or like cans and is transported by a special truck designed to handle the dumpster pan or by a truck suitable for transporting cans or drums. Handling methods are dictated by normal health physics procedures and are designed to miminimize radiation exposure to personnel, to prevent the possibility of contamination, and to meet the principles of industrial safety.

In cases where the material involves high radiation or is too bulky or heavy to be handled by ordinary means, special equipment (i.e., mobile cranes, high capacity floats, or shielded equipment) may be used for loading and transportation. In all cases where rigging equipment is used, the appropriate safety standards for such equipment must be met. Standard procedures are developed for those cases where the heavy shipments are handled frequently.

The movement of the waste from the point of origin to the disposal area is over roads completely internal to the ORNL reservation, except for those infrequent cases where waste is shipped in from offsite. When deemed necessary, special precautions are taken to ensure isolation of the shipment; these could include temporary restrictions on the route, the presence of an escort, or other suitable precautions.

The SWS Area foreman is directly responsible for compliance with regulations applicable to operations within the area. Regulations require that:

1. Work is performed in a safe manner, using appropriate protective clothing, personnel meters, instrumentation, and equipment to avoid inhalation and/or ingestion, to minimize personnel exposure and spread of contamination.
2. Work is performed with periodic HP checks if work is routine and with complete HP surveillance when it is not or when situation warrants or supervision directs.

3. ERDA-ORO owned equipment and apparatus retained for routine use in the area are kept within practical working limits for transferable contaminants as established jointly between the foreman and the HP field surveyor and approved by the supervisor of SWS operations.

4. Equipment and apparatus not normally engaged in routine repetitive burial or storage operations is free of transferable contamination prior to release from area control.

Upon arrival at the disposal area, the waste is stored in an appropriate manner in one of the facilities described in Section II. The method of handling depends upon the type and physical form of the material.

(b) Fissile Alpha Waste

For fissile alpha waste, an Authorization for Storage of Radioactive-Contaminated Solid Waste (Fig. 33) and a Record of Transactions of Source and Special Nuclear Materials (Fig. 34) are required by the SWSA foreman prior to accepting the responsibility for these materials. A Request for Nuclear Safety Review (Figs. 35 & 36) must be processed if the quantities involved exceed those listed in Table 2.

After the necessary paper work has been completed, the containers, properly labeled with a Radiation Hazard Material Transfer Tab (Fig. 37) are picked up on request. The heavier containers such as concrete casks and shielding drums are transported with the aid of rigging equipment (e.g., "floats" and mobile cranes).

These materials must be stored in retrievable fashion. Concrete casks are placed in trenches using a crane, and shielded drums and capsules are placed in auger holes in Building 7827 or 7829 (Fig. 17).

AUTHORIZATION FOR STORAGE OF RADIOACTIVE-CONTAMINATED SOLID WASTE

ORIGIN (BLDG. IF ORNL)	SECTION OF BLDG.	DESCRIPTION OF CONTAINER(S)
NO. OF CONTAINERS	VOLUME OF WASTE TOTAL CU FT % BURNABLE	

TYPE OF WASTE ☐ GENERAL RAD WASTE ☐ FISSILE (U-235) ☐ TRANSURANIUM OR U-233 ☐ OTHER (EXPLAIN IN REMARKS)

TOTAL RADIOACTIVITY CURIES

REMARKS RE WASTE CONTENT AND/OR HANDLING PROCEDURES

REQUESTER'S AUTHORIZATION FOR MATERIAL DISPOSAL		
	SIGNATURE	PHONE NO
	BADGE NO	DATE
	DIVISION	ACCOUNT NO.

TRANSURANIUM CONTAMINATED WASTE

SPECIFIC RADIOTOXICITY > $10 \mu Ci/Kg$ ☐ YES; ☐ NO

ISOTOPE(S) PRESENT AND ISOTOPE QUANTITIES:

☐ Pu-239 ________ grams

☐ U-233 ________ grams

☐ OTHER (If Significant, Detail in Remarks)

FISSILE WASTE

☐ U-235 ________ grams of Enrichment ________ %

☐ OTHER (Detail in Remarks)

ACCOUNTABILITY NO.

NSR ________ ; SNM ________ .

MAIL FORM OR TELEPHONE STORAGE AREA FOREMAN FOR CONCURRENCE PRIOR TO MATERIAL TRANSFER (EXTENSION 3-6356)

RADIATION LEVEL

BETA GAMMA: SHIELDED (OUTSIDE REUSABLE CARRIER) mrem/hr @ inches; UNSHIELDED (OUTSIDE OF DISPOSABLE CONTAINER) mrem/hr @ inches.

NEUTRON READING mrem/hr

SURFACE CONTAMINATION BETA GAMMA d/minute ALPHA d/minute

☐ H.P. TO ACCOMPANY SHIPMENT ☐ H.P. TO BE PRESENT DURING STORAGE ☐ RESPIRATORY PROTECTION REQUIRED

REMARKS REGARDING SAFETY IN HANDLING AND/OR STORAGE AND BURIAL

SPECIAL PROTECTIVE EQUIPMENT
(For Storage or Burial)

☐ COVERALLS, TAPED

☐ COVERALLS, 2 PAIR

☐ HEAD COVER

☐ ASSAULT MASK

☐ CHEMOX MASK

☐ OTHER (DETAIL IN REMARKS)

HEALTH PHYSICS APPROVAL FOR MATERIAL TRANSFER	SIGNATURE	BADGE NO.	PHONE NO.	DATE

ABOVE INFORMATION FOUND VALID?

☐ YES ☐ NO (IF NO, EXPLAIN)

REMARKS

WASTE: ☐ STORED; ☐ BURIED; IN SWSA NO. ________ .

TRENCH TYPE AND NO.	WELL TYPE AND NO.	FFO	FFT
BUILDING NO.	COMPARTMENT	LEVEL	SWSA I.D.

OTHER (EXPLAIN)

VOLUME (CU. FT.) TOTAL ; BURNABLE ; NON-BURNABLE — CONTAINER TYPE

SUPERVISOR'S RECEIPT OF MATERIALS	SIGNATURE	BADGE NO.	DATE STORED

UCN-2822
(23 4-75)

DISTRIBUTION: WHITE - STORAGE AREA FOREMAN RETAINS
BLUE - COMPLETED AND RETURNED TO ORIGINATOR
CANARY - RETAINED BY ORIGINATOR

Fig. 33. Authorization for storage of radioactive-contaminated solid waste.

OAK RIDGE NATIONAL LABORATORY

RECORD OF SSN TRANSACTIONS

(Intra-ORNL Only)

JEV NUMBER	TRANSFER NO.
	SNM –

FROM:

1. BALANCE AREA	2. CONTROL AREA	3. MATERIAL STATUS	4. DATE
5. PROJECT NUMBER		6. TYPE TRANSACTION	

7. SIGNATURES

SENDER

BALANCE AREA REPRESENTATIVE

TO:

1. BALANCE AREA	2. CONTROL AREA	3. MATERIAL STATUS	4. DATE
5. PROJECT NUMBER		6. TYPE TRANSACTION	

7. SIGNATURES

RECEIVER

BALANCE AREA REPRESENTATIVE

WEIGHTS IN GRAMS

		COLUMN NUMBER	1	2	3	4
10. Nuclear Material Code	11. Wt. % Isotope	8. Item No.				
		9. Chemical or Physical Form				
		12. Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
13. Estimated Limit of Uncertainty per Column		Element(s)				
		Isotope(s)				
14. Number of Pieces						
15. Container Number						
16. NSR Assigned to Container or Transfer						
17. Analytical Report Number						
18. Assay Report Number						
19. Gross Weight of Container and Material - Lbs						
20. Net Weight of Material - Grams or Volume						

NOTE: SHIPPER-RECEIVER DIFFERENCES MUST BE REPORTED TO SS OFFICE IMMEDIATELY FOR RECONCILIATION

OTHER PERTINENT COMMENTS

DISTRIBUTION: (White) Accountability Office - (Canary) Receiver - (Blue) Shipper

UCN-2681
(3 7-72)

Fig. 34. Oak Ridge National Laboratory record of SSN transactions.

REQUEST FOR NUCLEAR SAFETY REVIEW

This request covers operations with fissile material in a control area and/or fissile material transfers that originate within the control area. The control area supervisor shall complete the blocks below and describe the process and/or operations to be performed, emphasizing the provisions for nuclear criticality safety on the reverse side of this page. This request shall be approved by the Radiation Control Officers of the originating Division and the Division(s) to which fissile material will be transferred.

EXPIRATION DATE

TITLE, CONTROL AREA, AND SUMMARY OF BASIC CONTROL PARAMETERS

(To be completed by the Control Area Supervisor)

TITLE (FOR REFERENCE PURPOSES)			DATE OF REQUEST	DATE REVIEW REQUIRED
CONTROL AREA	CODE NO.	BUILDING ROOM	DIVISION	

TYPE AND FORM OF MATERIAL		
ISOTOPIC ENRICHMENT (Wt. %)		
QUANTITY OF FISSILE ISOTOPES	PER ISOLATED BATCH OR UNIT	
	TOTAL IN CONTROL AREA	
	TOTAL TO BE PROCESSED	
Concentration or Density of Fissile Material		
Spacing of Fissile Units		
Proximity and Type of Neutron Reflectors or Adjacent Fissile Material		
Limit on Moderation		
Limit on Neutron Absorbers		
Limit on Volume or Dimensions of Containers		

THIS REQUEST (MODIFIES, REPLACES) NSR(S) NO.

RECOMMENDATIONS

(To be completed by the Criticality Committee)

This endorsement is based on our present understanding of the operation (whether acquired verbally or in writing) and is subject to review and cancellation.

CHAIRMAN, CRITICALITY COMMITTEE   DATE

UCN-5917
(3 9-70)

Fig. 35. Request for nuclear safety review (UCN-5917).

PROVISIONS FOR NUCLEAR CRITICALITY SAFETY
(To be completed by the Control Area Supervisor)

Provisions for nuclear criticality safety shall be described below in accordance with Appendices II and III of the AEC Manual Chapter 0530. This shall include brief descriptions of the process and/or all operations to be performed, plans and procedures for the operations for nuclear criticality safety, and the basic control parameters Please attach 11 copies of referenced drawings and documents.

EXPIRATION DATE

RADIATION CONTROL OFFICER	DIVISION	CONTROL AREA SUPERVISOR	BUILDING
RADIATION CONTROL OFFICER	DIVISION	RADIATION CONTROL OFFICER	DIVISION

Fig. 36. Request for nuclear safety review (UCN-5917).

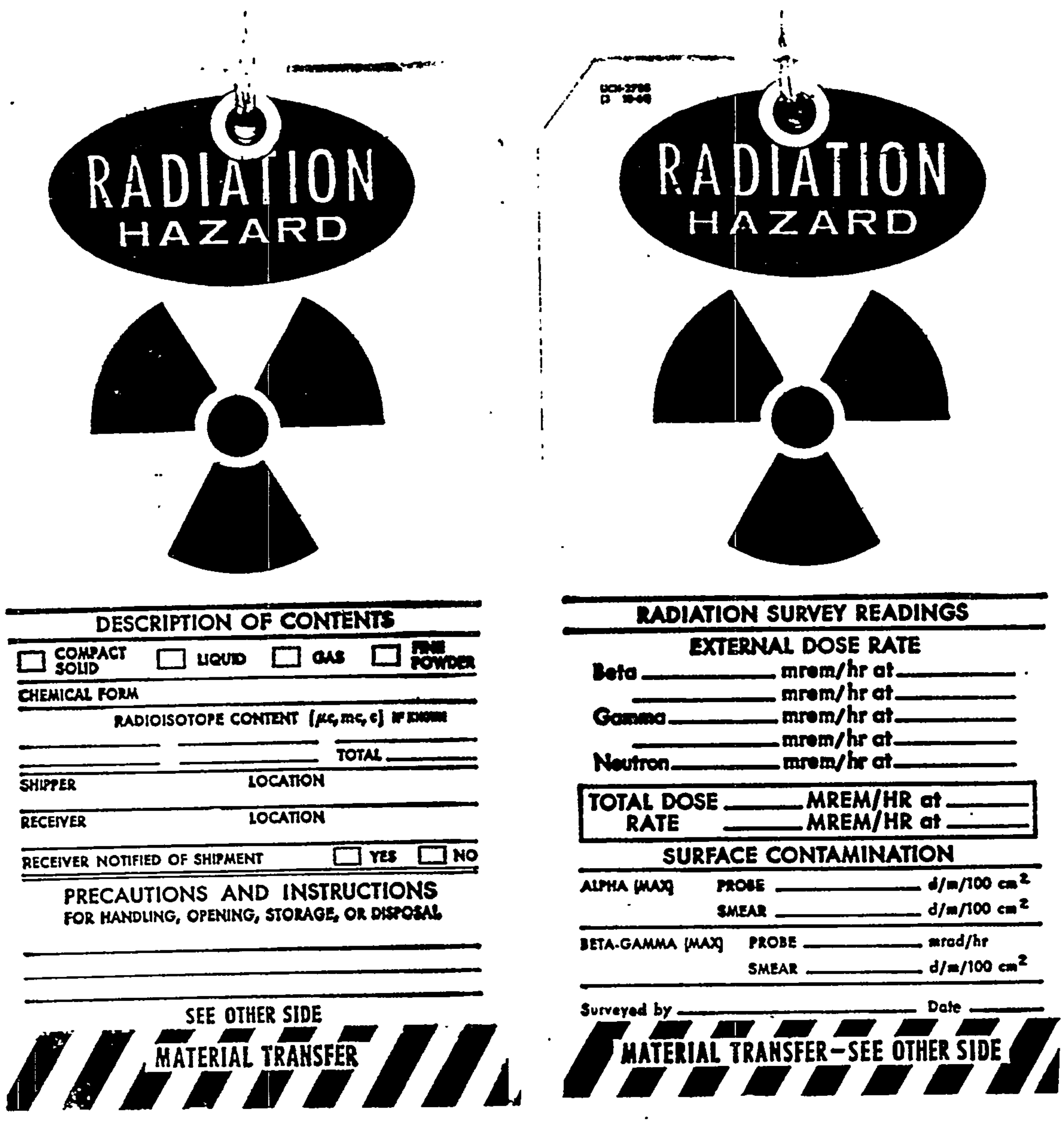


Fig. 37. Radiation hazard material transfer tag (UCN-2785).

Wastes are placed in suitable containers at the point of origin because facilities for repackaging are not available at the SWSA's. Three types of containers routinely used for packaging fissile alpha waste are concrete casks (Figs. 16a, 16b, and 16c), stainless steel drums (30 and 55 gal capacity), and stainless steel capsules of special design. The choice of package depends upon the amount of direct beta-gamma and/or neutron radiation (external surface readings above or below 200 millirads/hr) associated with the contents. In all cases, the originator is responsible for compliance with the health physics regulations regarding radiation and surface contamination.

The loaded casks are transported from the point of origin by tractor-trailer and placed in trenches by means of a mobile crane. Casks with burnable only waste are segregated from casks containing non-burnable or mixed waste. When full, the trenches are backfilled (3 ft of Conasauga Shale overburden) and their location can be determined from the metal casing of the observation well in each trench or resurveyed from engineering data. Records are kept on the location and contents of each trench.

Low level fissile alpha waste is stored in drums and does not require shielding. The drums are shipped by truck and unloaded either by hand or with the help of rigging equipment. They are stacked in Building 7823 with the aid of a forklift truck until sufficient quantity (64 minimum) is on hand before transfer to Building 7826. Prior to shipment to the SWSA, the outer surfaces of these containers are decontaminated to such an extent that no special dress precautions other than Company-issued clothing are needed.

Material stored in stainless steel drums or capsules is identified by metal tags and all pertinent information is recorded for each tagged container. Through June 1976, 31,944 ft^3 of waste have been retrievably stored at ORNL. This was accumulated at a calculated average annual rate of 5,637 ft^3. Storage costs are increasing; the most recent cost reported under the provisions of the Solid Waste Information Management System (SWIMS) is $30.00/$ft^3$.

Criticality control of these materials is maintained by restricting the quantity of fissionable material* placed in each type of container (see Table 2). These restrictions are consistent with the requirement that the concentration of fissionable material shall not exceed 5 g/ft^3, at which level an infinite array of such containers has a multiplication constant well below unity. In any case, where the amount of fissionable material to be stored exceeds the quantities listed in Table 2, or 5 g/ft^3 for other containers, the originator of the waste must obtain prior approval from the ORNL Criticality Committee. Under certain circumstances this Committee may, after due consideration, modify the requirements of Table 2 for individual packages.

The precautions and dress required for the field crew for these operations are based on the findings of the field health physics surveyor and those entered by the area health physics surveyor on the Authorization for Storage of Radioactive-Contaminated Solid Waste prepared

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* Fissionable material means ^{233}U, ^{235}U, or ^{239}Pu. Very small quantities of transuranium isotopes may be present, some of which are fissionable. Control of these materials is on individual basis.

jointly by him and the originator of the waste. In most cases, Company-issued clothing is adequate; however, under some circumstances, contamination zone procedures may be necessary.

(c) Fissile Non-Alpha Waste

Fissile non-alpha waste (enriched uranium-235, uncontaminated with fissile alpha nuclides) is collected by SWSA crew from the originator upon request and buried in unlined auger holes (not more than 200 g/hole). Prior to transferring responsibility for this waste to the SWSA foreman, the originator must prepare an Authorization for Storage of Radioactive-Contaminated Solid Waste, describing the material and any special precautions required. In addition, a Record of Transactions of Source and Special Nuclear Materials must be completed. This document, which specifies the type and quantity of material involved, is required for accountability purposes. In cases where the amount of fissionable material in a container exceeds 200 grams, the originator is required to process a Request for Nuclear Safety Review. This request is reviewed by ORNL Criticality Committee, and disposal of the material must be handled in accordance with the recommendations of the Committee.

Unpackaged bulk material containing less than 1 g/ft^3 of fissionable isotopes is buried in unlined trenches under standing agreement with the ORNL Criticality Committee.

Fissile non-alpha waste is packaged in containers suitable for safe transport to the ORNL burial ground and surveyed by a health physics surveyor who affixes a properly completed Radiation Hazard Material Transfer Tag to the container. The package, in a shielded or unshielded condition, is then conveyed to the SWSA where it is placed in an unlined auger hole and covered with 3 ft of concrete and dirt. When a shielded container is used, mobile lifting equipment is necessary; otherwise, the container may be moved by hand and transported by truck.

In no case can a single package contain more than 200 g of fissile material unless prior approval is obtained from the ORNL Criticality Committee. The originator of the fissile waste is required to give advance notice to SWSA foreman of the pending need for service.

Company-issued clothing is used for this operation, and radiation monitoring, if necessary, is handled by health physics personnel. Shielded containers may be either top- or bottom-loading and, if required, temporary means are devised to shield personnel during the transfer of material from container to the auger hole.

Through June 1976, some 11,000 ft^3 of fissile waste have been buried at ORNL in separated zones of the SWS areas. Since FY-1970, when segregation of waste by these isotopes was begun, accumulation was at a calculated average approximate rate of 1,600 ft^3/yr; however, only 123 ft^3 were handled in FY-1976. Burial costs are considered to be the same as that of radwaste: \$2.50/ft^3.

(d) General Radwaste

General radwaste disposal is accomplished by depositing the waste below grade in trenches or in auger holes. Once the trench is filled to within 3 ft of grade, it is backfilled with earth. Six-inch perforated metal well casing is used as a trench marker and may have a metal tag identifying the trench by number attached to it. All trench details are maintained on as-built drawings, and a log describing the history of the trench is maintained.

Low and intermediate level general radwastes are routinely removed from the point of origin in dumpsters or in metal waste cans. Service is provided primarily on an "on-call" basis. The material is packaged by the originator and, when ready for shipment, surveyed by a member of the Radiation Safety and Surveys Section to determine if the material indeed is low or intermediate level general radwastes. A Radiation Hazard Material Transfer Tag is affixed, which describes the contents and the results of the survey. The waste is then picked up and transported to the SWSA where it is emptied into a disposal trench without being reopened. Radiation monitoring in this case is routine and is guided by the original survey. Company-issued clothing is worn by the crew.

High level general radwaste with a surface radiation level in excess of 200 mR/hr and certain other hazardous types of material such as sodium and potassium are also removed from the point of origin on an "on-call" basis. Shipment and storage of materials of this type are treated individually by procedures appropriate for the particular situation involved. Each container is loaded by the originator and surveyed by health physics personnel; as in the previous case, a Radiation Hazard Material Transfer Tag is affixed. In addition, the originator and the area health physics surveyor are required to complete an Authorization for Storage of Radioactive Contaminated Solid Waste. This form contains a description of the material and specifies the precautions to be taken during handling and storage. The SWSA foreman reviews this form prior to accepting the material and, together with the field health physics surveyor, determines the proper handling procedures. After making the necessary preparations, the foreman approves the transfer. This type of waste is placed either in a trench or auger hole.

If transported in lead-lined Dumpster pans, the waste is emptied into a trench using a motor crane. Usually, several pans are emptied at one time. Pans being held at the SWSA for emptying are stored under a protective rain shield.

Shielded carriers of high level radioactive waste are transported by truck or yard crane and unloaded, using mobile lifting equipment. Top-loading carriers are used as infrequently as possible, but, if used, they are lowered into the trench, using a crane, and then inverted to empty the contents. Bottom-loading carriers are suspended in the trench and emptied.

Some high level waste is received in 55-gal drums transported in a shielded carrier. The drums are lowered by means of a mobile crane through the bottom of the carrier after it has been placed over an auger hole and the discharge port opened. In most cases, the likelihood of contamination is sufficiently low that only Company-issued work clothing is required for this operation.

After emptying, carriers are reassembled, closed as required, wiped externally, and surveyed by a health physics surveyor before being wrapped in plastic and returned to the owner.

Bulk shipments of high level general radioactive waste, such as contaminated earth or construction debris, are usually received in a dump truck or on a float. The material is placed in the trenches using a crane when conditions dictate; otherwise, it is merely dumped. A health physics surveyor is in attendance during these operations and assists the foreman in determining the degree to which personnel are required to dress out in contamination zone clothing and to observe precautions prescribed for contamination zone operations. All dumping operations are carried out only under appropriate meteorological conditions (e.g., low wind speed).

Shipments of radioactive waste materials, which must be regarded as non-routine for reasons other than high level radiation, are handled on a case-by-case basis in accordance with procedures developed by the SWSA foreman after consultation with the health physics surveyor, his Division Radiation Safety and Control Officer, his supervisor, and/or other advisory groups as deemed necessary.

All crew members are required to wear film badges, personal dosimeters, and pocket meters. Dosimeters are read by the wearer and verified by the foreman as required. The pocket meters are read daily by personnel of the Radiation Monitoring Section of the Health Physics Division. Film badges are processed quarterly by Health Physics and when otherwise deemed advisable.

Through June 1976, an estimated 6,500,000 ft^3 of radwaste have been buried in the ORNL burial grounds. The rate of burial has decreased to an average of approximately 100,000 ft^3. Burial cost is $\$2.50/ft^3$.

III. OPERATING PRACTICES

B. Assessment

1. Introduction

The policy of the Oak Ridge National Laboratory is to conduct its operations in a fashion that will ensure the control of all potentially harmful effects to persons, to the environment, and to facilities and equipment. The operations associated with the storage of solid waste are carried out in accordance with this policy.

Operational hazards related to waste storage and burial practices are twofold. First, an exposure and contamination hazard exists because of the radioactive nature of the waste materials. Secondly, ordinary day-to-day industrial safety hazards are associated with equipment operation, excavation and transportation activities, and the execution of routine labor activity. Safety standards and operational procedures have been established for personnel protection. Furthermore, corrective measures have been implemented to decrease the discharge of radionuclides from the burial grounds and thereby decrease the environmental hazard associated with burial operations. Thus, operational and environmental hazards associated with burial operations have been identified and precautionary and/or corrective measures have been devised to minimize their effect.

2. ORNL Radiation Protection and Safety Policy

(a) Radiation protection policy

The radiation safety policy of the Oak Ridge National Laboratory is specifically set forth in Section 1.1 of the ORNL Health Physics Manual.

This policy requires that all operations be conducted in a manner which ensures that radiation exposures to personnel will be maintained at a reasonably low level and will in no case exceed the standards established by ERDA; and that every effort will be made to perform the work in such a way that losses of material and equipment as a result of contamination will be minimized. Moreover, environmental contamination must be maintained at as low a level as possible, consistent with sound operating practice. In no case should environmental contamination outside the controlled area be permitted to exceed the maximum permissible concentration values applicable to individuals residing in uncontrolled areas.

(b) Safety policy

The specific objectives of the ORNL safety policy are contained in a document entitled, "The Safety Program of the Oak Ridge National Laboratory," and are designed to fully satisfy the safety requirements of AEC Manual Chapter 0550. The ORNL safety policy includes the requirements that all activities be conducted with the lowest reasonable risk of personal injury or property loss, that all work be performed in accordance with Laboratory safety regulations and designated national codes and standards, and that all significant accidents be investigated to determine their cause and to prevent their recurrence.

(c) Implementation

(i) Operational safety

Implementation of these policies is regarded at ORNL as a line organization function, and direct responsibility for the operational safety of the solid waste storage activities rests with the supervision and personnel of the Operations Division. The division safety officer represents the division in matters of safety and, at the division level, discharges the responsibilities designated by the division director. Members of the Radiation Surveys and Industrial Safety Section of the Industrial Safety and Applied Health Physics Division are responsible for auditing Laboratory safety practice, and are available to advise the Operations Division on the safe conduct of its work. The Manager for Laboratory and Personnel Protection represents the Laboratory Director in all safety matters and, with the aid of the Radioactive Operations Committee, the Criticality Committee, and the Transportation Committee, conducts periodic audits and reviews of the procedures and practices utilized by solid waste storage operations.

(ii) Environmental safety

Although protection against environmental hazards is also basically a line organization function, the implementation of environmental safety precautions is treated in a Laboratory-wide manner because of the complex nature of the problem. Appropriate procedures and guidelines have been developed to ensure that all of the Laboratory operations remain well within the limits set forth in ERDA Manual Chapter 0524, Standards for Radiation Protection.

In order to ensure that solid waste storage operations are carried out in a manner consistent with these limits, the procedures and practices are reviewed and audited by the Office of Laboratory and Personnel Protection, the Committees named above, and, in some cases, the Health Physics Division, the Environmental Sciences Division, or by special groups convened to examine particular problems.

Offsite monitoring for the presence of radioactive materials is carried out by the ORNL Industrial Safety and Applied Health Physics Division with the assistance of the ORNL Environmental Sciences Division which also carries out special studies to determine the effects of radioactive effluents on the local environment. Routine onsite monitoring is handled by the Laboratory Facilities Department of the Operations Divison.

3. Operational hazards

(a) Radioactive

(i) Radiation and contamination hazards

Radiation hazards to personnel engaged in the dipsosal of solid wastes are generally of two types: direct radiation, usually electromagnetic in character, that results from activation or contamination of the waste material; and contamination that may be transferred from the waste material and pose a hazard as a result of ingestion or inhalation, or by direct contamination of the skin and clothing. Contamination with alpha-emitting material is generally considered most dangerous because of the high energies involved and the fact that, when unaccompanied by beta-gamma radiation, alpha particles are frequently difficult to detect.

Protection against direct radiation and contamination is provided for by strict adherence to standard procedures designed to ensure proper packaging, shielding, and handling of the waste. These procedures delineate the methods to be used in various situations and specify the type of protective clothing to be worn and the kind and extent of radiation monitoring required.

A radiation work permit or equivalent is required in advance of any work assignment where an individual might receive a radiation dose in excess of 20 mrem/day to the body or 300 mrem/day to the extremities, or where the individual will encounter airborne radioactivity greater than MPC for a 40-hr week. Special approvals are required where radiation or contamination may be in excess of these values.

The radiation work permit (Figs. 38a and 38b) is authorized by the member of supervision responsible for the work being done, and must be certified by a representative of the Industrial Safety and Applied Health Physics Division. As can be seen, the permit describes the location and the job, contains information concerning the type and magnitude of the radiation hazard involved, and specifies the precautions and necessary protective equipment and monitoring instruments required. In addition, all personnel involved in waste storage operations are required to wear film badges, pocket meters and, as needed, personal dosimeters. The pocket meters are read daily by the Radiation Monitoring Section of the Industrial Safety and Applied Health Physics Division. The dosimeters are read as the job progresses and upon completion of the job.

The procedures followed to prevent direct radiation exposure and contamination during the waste handling operations were described in Part III. A. The overriding precept is constant vigilance and surveillance by direct supervision and by the individuals performing the work, all of whom have received training in radiation safety. In many cases assistance is also provided by members of the Radiation Safety and Surveys Section who are present whenever potentially hazardous operations are in progress.

RADIATION WORK PERMIT (RWP)

DATE AND TIME FROM	AM PM	TO	AM PM	EXTENDED BY TO	AM PM	WORK PERMIT NO. R- 42100

LOCATION & JOB DESCRIPTION

RADIATION SURVEY DATA (To be filled in by Health Physics)

LOC. CODE	SPECIFIC LOCATION AND DISTANCE FROM SOURCE	TYPE OF RADIATION	mrem/hr.	WORKING TIME FOR ______ mrem	CONTAMINATION TYPE	CONTAMINATION MEASUREMENT	RADIATION SURVEY BY	RADIATION SURVEY DATE AND TIME
A								
B								
C								
D								

INSTRUCTIONS*

HEALTH PHYSICS MONITORING REQUIRED: ☐ START OF JOB ☐ INTERMITTENT ☐ CONTINUOUS ☐ END OF JOB

CONTACT HP FOR SURVEY BEFORE STARTING WORK IN A NEW LOCATION	PROVIDE ASSISTANCE FOR REMOVAL OF PROTECTIVE CLOTHING
TAPE COVERALLS TO GLOVES AND FOOTWEAR	MONITOR BREATHING ZONE
CHECK TOOLS AT END OF JOB	NASAL SMEAR REQUIRED
CHECK PERSONNEL AT END OF JOB	BIOASSAY SAMPLE REQUIRED
TIMEKEEPING REQUIRED	DO NOT WORK ALONE-STANDBY OBSERVER REQUIRED

REMARKS

PROTECTIVE EQUIPMENT AND MONITORING INSTRUMENTS

CAP	COVERALLS (1 PR.)	SHOE COVERS	POCKET METERS
CANVAS HOOD	COVERALLS (2 PR.)	C-ZONE SHOES	DOSIMETER
SAFETY GLASSES	GLOVES: CANVAS	RUBBERS	FILM RING
EYE SHIELD	GLOVES: LEATHER	RUBBER BOOTS	DOSE-RATE ALARM
HALF MASK	GLOVES: SURGEON'S	PLASTIC BOOTEES	DOSE ALARM
ASSAULT MASK	GLOVES: PLASTIC	LAB COAT	CUTIE PIE
CHEMOX MASK	GLOVES: RUBBERIZED CANVAS	SPECIAL FILM METER	GMS METER
AIR-LINE HOOD	GLOVES: HOUSEHOLD RUBBER		
AIR-LINE SUIT			

REGULAR APPROVALS	SPECIAL APPROVALS
HEALTH PHYSICS CERTIFICATION	DIVISION DIRECTOR
SUPERVISION	H.P. DIVISION DIRECTOR
SUPERVISION	DEPUTY LAB DIRECTOR

UCN-2779 (3 7-61)

*Only items checked (√) apply.

(OVER)

Fig. 38a. Radiation work permit (UCN_2779).

1. Health Physics shall be present for line breaks or removal of shielding.
2. Notify Health Physics of any deviations from instructions and changes in working conditions.
3. Personnel survey is required when leaving contamination zones.
4. Return work permit to Health Physicist upon completion of job or expiration of permit.

TIMEKEEPING BY ____________

DEPT. ____________

PERSONNEL AND EXTERNAL EXPOSURE CONTROLS						PLANNED EXPOSURE (mrem)	TIME RECORD							ESTIMATED EXPOSURE (mrem)
NAME	DEPT.	P.R. NO.	LOCATION CODE	DOSE RATE USED	WORKING TIME		BEGIN	END	BEGIN	END	BEGIN	END	TOTAL TIME	

1. **Radiation Work Permit is required* when:**
   (a) expected dose is >20 mrem to the body or 300 mrem to extremities for an individual during a single work assignment;
   (b) dose rate >5 rem/hr (total body);
   (c) airborne radioactivity is > $(MPC)_a$ for a 40-hr week;
   (d) specified by divisional operating rules and procedures or by posted regulations.
2. **Supplementary Time Sheet**
   To be used if extra space is needed for the timing of individuals into and out of an area, etc.
3. **Special Approvals**
   (a) Dose Rate rem/hr (total body)

>5	Division Director in charge of work area	Oral or written; noted and initialed on the permit by the person obtaining the approvals.
>20	Above and Health Physics Division Director.	
>50	Above and Laboratory Deputy Director.	

   (b) Dose (total body)

>60 mrem/day for nonoperating personnel, or >300 mrem/wk for operating personnel	Division Director in charge of individual
>1 rem	Above and Laboratory Deputy Director

4. **Copies**
   (a) The RWP must be posted or available at work site.
   (b) Health Physics maintains a copy for record and reference purposes.
   (c) A copy must be distributed to appropriate line supervision.

*Posted regulations may be used in lieu of an RWP for *operating personnel* under specified conditions. (See Regulation 3, Procedure No. 26, ORNL Health Physics Manual.)

Fig. 38b. Radiation work permit (UCN-2779).

(ii) Criticality hazards

Criticality is prevented by strictly limiting the amount of material to be handled in a single package or disposed of in a given storage facility. The quantities of fissionable material that may be stored in a single container (Table 2) were established so that an infinite array of containers would be safely subcritical. Bulk material containing less than 1 g/ft^3 of fissionable material may be safely stored in a semi-retrievable fashion because it is sufficiently dilute so that no possibility of criticality exists.

Note that the foregoing restrictions on criticality apply strictly to combinations of the more common fissionable nuclides, namely ^{235}U, ^{233}U, and ^{239}Pu. Certain of the transuranium isotopes such as ^{242}Am, ^{245}Cm, and several of the californium isotopes are known to have very small minimum critical masses.

In any case where a question regarding criticality safety exists, or where for some reason the specified limits must be exceeded, the problem is submitted to the ORNL Criticality Committee for review and recommendations.

(iii) Neutron sources

Occasionally, neutron-emitting wastes must be stored. Usually, these wastes consist of fissile alpha transuranium wastes that contain trace amounts of the neutron-emitting "even-even" nuclei. These materials are normally handled by utilizing shielded containers that reduce the neutron emission to levels sufficiently low to meet the requirements of ORNL radiation protection policy.

Certain materials such as beryllium and deuterium emit neutrons when exposed to high energy sources of electromagnetic radiation. When possible, these photoneutron sources are disassembled prior to disposal; however, when this is not feasible, they are appropriately shielded prior to handling and transportation to the SWSAs. Health physics and supervisory surveillance requirements similar to those employed in handling other radioactive wastes are observed.

(b) Industrial

The normal industrial hazards that accompany the solid waste storage operation are similar in character to those associated with an operation involving excavation, lifting, hauling, and the employment of heavy construction equipment. As is the case with radiation induced hazards, protection is afforded by constant vigilance and surveillance by direct supervision and by the individuals performing the work, all of whom receive training in the fundamentals of industrial safety.

The policy of ORNL is to prevent personal injury and property damage by maintaining standards of safety consistent with national codes and standards. The following list contains the standards having particular application to the solid waste disposal operations:

ERDA Manual Chapter 0550 - Operational Safety Standard

ERDA Manual Chapter 0522 - Industrial Fire Protection

ORNL Standard Practice Procedure 16 - Safety Standards

ORNL Standard Practice Procedure 17-D -Laboratory Emergency Planning and Evaluation

ORNL Standard Practice Procedure 35-B - Industrial Health Series

ORNL Standard Practice Procedure 55-D - Fire Prevention and Control

ORNL Safety Manual

Occupational Safety and Health Act, in particular, Sections 1910 and 1926

Plant and Equipment Division Safety Manual

Plant and Equipment Division Procedures:

- M.3.4 Solid waste disposal cask - TRU facility
- M.3.6 Handling and transfer of shielded carriers
- M.3.9 Qualification tests for industrial operation lift trucks

Inspection Engineering Manual:

- Section 1. Inspection of purchased material
- Section 9. Visual inspection
- Section 10. Upgrading materials
- Section 14. Inspection of testing and hoisting equipment

As a result of vigorous prosecution of its safety program, the Laboratory has achieved in the past, and continues to achieve an outstanding record of industrial safety. This record is graphically illustrated by the statistics given in Table 9.

4. <u>Environmental Hazards</u>

(a) <u>Storage and disposal facilities</u>

The primary purpose for disposing of solid waste by storing it below grade is to remove it effectively from the environment. While ground burial does accomplish this purpose over the short term, there is

Table 9. Comparison of disabling injury frequency rates of ORNL (from time of operation under contract with Union Carbide), NSC,[a] and ERDA.

Year	ERDA	NSC	ERDA
1948	2.42	11.49	5.25
1949	1.54	10.14	5.35
1950	1.56	9.30	4.70
1951	2.09	9.06	3.75
1952	1.39	8.40	2.70
1953	1.43	7.44	3.20
1954	0.79	7.22	2.75
1955	0.59	6.96	2.10
1956	0.55	6.38	2.70
1957	1.05	6.27	1.95
1958	1.00	6.17	2.20
1959	1.44	6.47	2.15
1960	0.94	6.04	1.80
1961	1.55	5.99	2.05
1962	1.45	6.19	2.00
1963	1.55	6.12	1.60
1964	1.07	6.45	2.05
1965	2.34	6.53	1.80
1966	0.64	6.91	1.75
1967	0.50	7.22	1.55
1968	0.13	7.35	1.27
1969	0.27	8.08	1.52
1970	0.76	8.87	1.28
1971	0.61	9.37	1.44
1972	1.08	10.17	1.40
1973	0.33	10.55	1.45
1974	0.81	10.20	1.60
1975	0.27	13.10	2.50
1976	0.13	NA	NA

[a]National Safety Council (NSC), all industries.

concern over the eventual fate of these radionuclides, especially those with long half-lives. Consequently, the current practice is to store these long-lived materials in a retrievable fashion pending the development of a more permanent method of storage.

The waste disposal and storage areas are located within the ORNL reservation on land owned and controlled by the U. S. Energy Research and Development Administration. The reservation is fenced, provided with appropirate warning signs, regularly patrolled, and access is prohibited to the public. Some areas of burial ground 5 are individually fenced with woven fabric as is all of burial grounds 3 and 6.

Current practice is to annually surface seal those portions of the disposal site that have been closed. This is accomplished by establishing a 3 in thick membrane of 12% approximate bentonite-Conasauga Shale mixture over the closed area, place a two ft deep cover of shale over the membrane, contour the area, and seed and fertilize for grass. Trees and underbrush that might send roots into the closed trenches are removed, and the area is posted to indicate its character. Hence, with the exception of a few seepage areas, the land surface is essentially free of contamination.

While the radiation level at the top of an open trench or auger hole may be as high as 200 mr/hr, the trench or auger hole is backfilled until the maximum radiation reading above the closed facility is 3 mr/hr or less. Usually, the actual radiation level from closed facilities is much lower.

The level of radiation in the aisles within the above-ground storage building is held to less than 10 mr/hr. Occsionally, containers with "hot spots" of varying levels are received. When these containers cannot be shielded with other containers in the building, special arrangements are made to reduce the radiation intensity to the appropriate level.

In any case, the burial grounds, the seepage pits and trenches, and the settling basins are all regarded as regulated, radiation, or contamination zones and are posted as such. Hence, there is little, if any, danger of a direct hazard to the public as a result of the presence of buried waste located in these areas. Two of the settling basins are located within the X-10 controlled area (waste pond no. 1 and waste pond no. 2). The HRT settling basin has been filled and covered with asphalt which prevents intrusion (also within the ERDA reservation). The seepage pits and trenches are also covered with asphalt with the exception of pit 4.

With three exceptions, no significant amount of rapidly available stored energy is associated with the waste. None of the material is under pressure; it is essentially chemically inert; and the possibility of inadvertent criticality is prevented by segregation and packaging precautions.

The exceptions involve the disposal by ground burial of small quantities of contaminated lubricants such as cutting oil and vacuum pump lubricant and the practice, now largely discontinued, of burying alkali metals. In addition, small quantities of pyrophoric materials such as metallic zirconium and magnesium must occasionally be disposed of. All of these materials are disposed of in separate trenches or holes at a sufficient distance from other trenches to prevent any interaction, should an energy release occur.

Waste material stored in a retrievable form in auger holes or above ground in burial ground 5 is within a fenced security area. The capped auger holes are shielded to reduce the direct radiation in their vicinity to an acceptable level, and the material stored above-ground in Building 7826 is controlled to meet health physics requirements. Thus, as in the case of the below-grade storage, these above-ground wastes which are located at least 1000 ft from the nearest public access do not present a direct hazard to the public.

(b) Burial ground corrective measures

The objectives of the investigations of the ORNL burial grounds are: to determine the contributions of radionuclides to the Clinch River from each burial ground, to characterize the sorption and transport mechanisms of more mobile radionuclides, and to seek engineering methods of reducing discharges of these radionuclides from the burial grounds. Early in these investigations it became apparent that ^{90}Sr was the radionuclide of greatest concern because of the concentrations in White Oak Creek at the point of release (monitoring station 5 at White Oak Dam, Fig. 39). Other radionuclides do not exceed recommended concentrations for release to a population at this sampling station (code of Federal Regulations, Title 10, Part 20). However, some work has been initiated in an attempt to understand transport and sorption mechanisms of other radionuclides in addition to ^{90}Sr (such as ^{60}Co and transuranics).

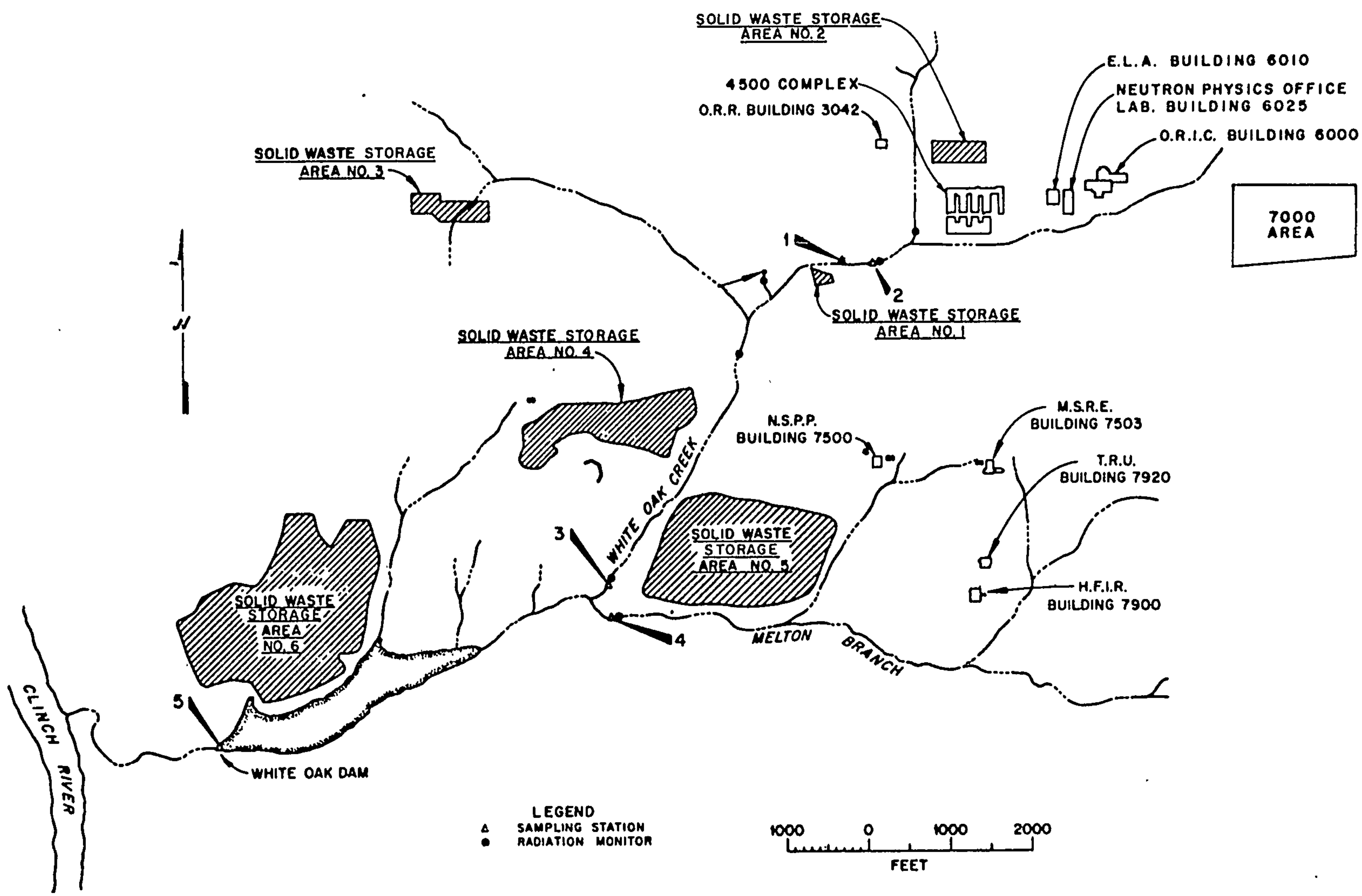
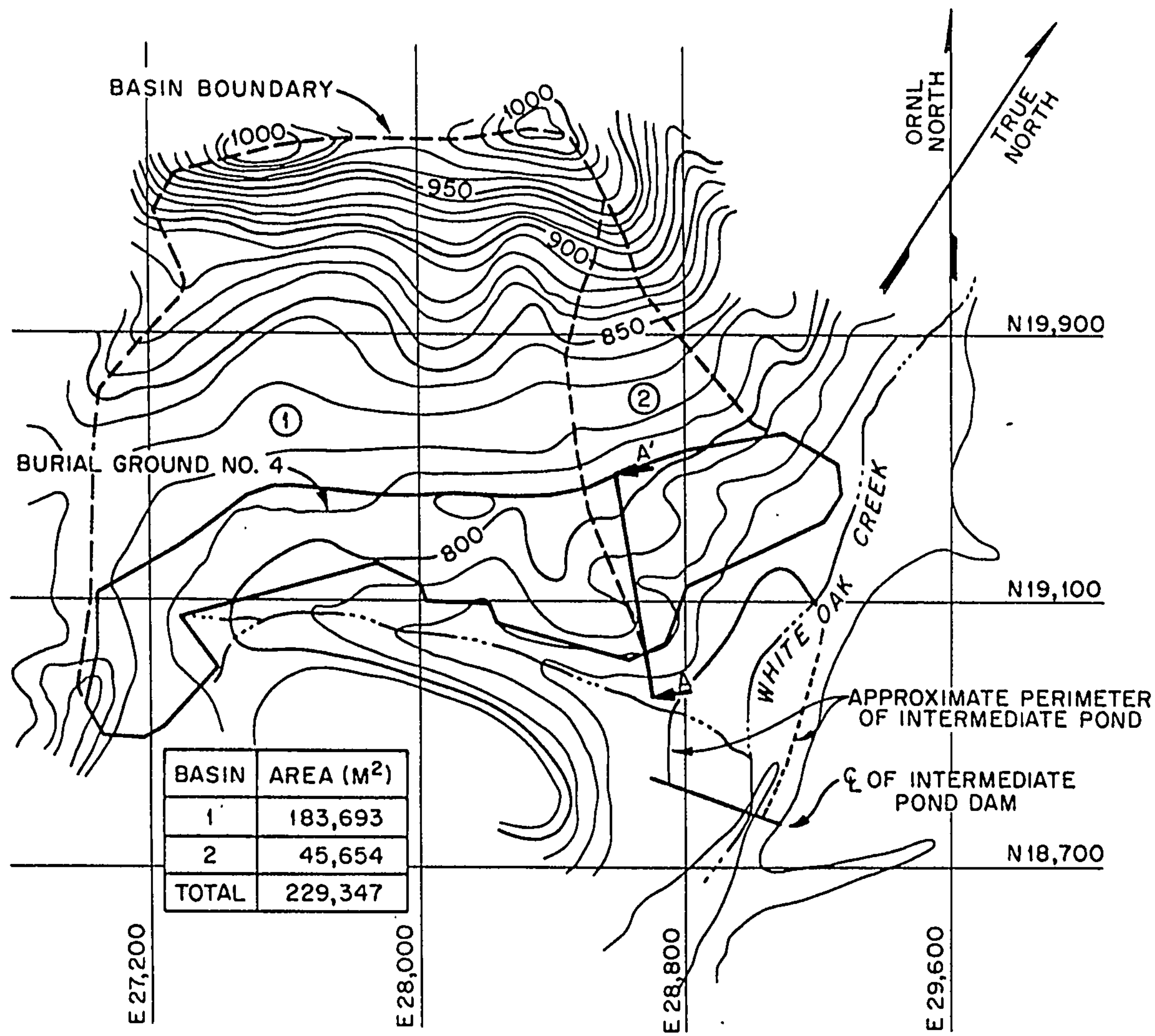


Fig. 39. Location plan of ORNL solid waste storage areas.

Within the first year of the burial ground studies it became apparent that the bulk of the ^{90}Sr released from buried waste at ORNL was coming from burial grounds 4 and 5. Thus, the studies have concentrated primarily on one radionuclide (^{90}Sr) and two burial grounds (burial grounds 4 and 5). A more detailed account of these studies is given by Duguid (1975, 1976).

This section contains a summary of corrective measures that have been and are being applied to reduce the discharge of radionuclides (primarily ^{90}Sr) from the buried waste. The measures are designed to improve current and past operating practices as well as serving to test new burial technology.

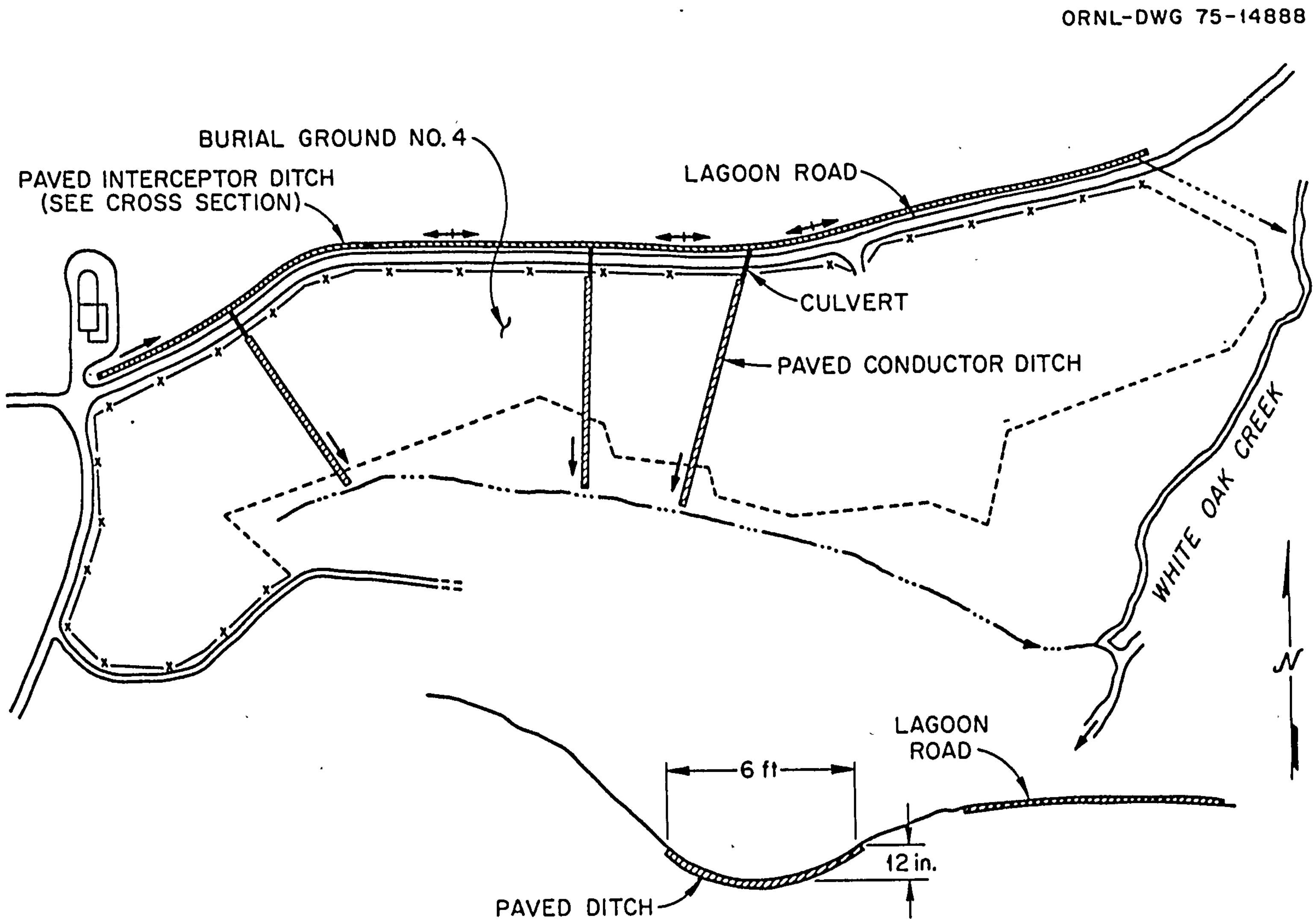
Because the transport of ^{90}Sr from the burial grounds has been shown to be a function of precipitation, corrective measures are designed to limit the amount of infiltration from precipitation. In the case of burial ground 4, no near-surface sealing has yet been attempted. However, a surface water diversion system was recently installed. This system collects surface runoff from the upper portion of the basin (Fig. 40) and transmits it across the burial ground (Fig.41). Prior to the installation of the surface water diversion system, surface runoff originating from the upper basin flowed onto the burial ground surface and infiltrated into the buried waste. Because of a malfunction of sampling station 3 (post-1974 but not discovered until 1976), no data are available on the effectiveness of the surface water diversion system. The result of this malfunction is reflected in the high ^{90}Sr



BASIN	AREA (M^2)
1	183,693
2	45,654
TOTAL	229,347

Elevation Contours Prior to the Establishment of Burial Ground No. 4. The Dashed Line is the Perimeter of the Drainage Basin which is Divided into Parts 1 and 2.

Fig. 40. Drainage basin in which burial ground 4 is located.



Typical Cross Section–Interceptor Ditch
(Conductor Ditch Similar)

Fig. 41. Surface runoff diversion for burial ground 4.

discharge for 1976 (see Table 6). The installation of new stream sampling stations is being planned (see Section II. B. 3.), and at least one year of sampling data will be required before an evaluation of corrective measures can be made. This one year of sampling data will also serve as background data to evaluate the effectiveness of near-surface sealing of burial ground 5.

In one specific area within burial ground 5 (trench 83) a small surface seep (S-4) developed during the wet winter months (Fig. 42). Because of the concentration of radionuclides (^{238}Pu, ^{244}Cm, and ^{90}Sr) in the seepage effluent actions were taken to eliminate this discharge. The seepage usually occurred in a period from January to April after the winter rains had infiltrated the trench and caused it to overflow. Corrective measures were proposed in July 1974 that would eliminate the downward movement of water into the trench.

The original proposal called for a bentonite-shale seal over trenches 105 and 83 at a depth of 2 ft (Fig. 43) and for at least two vertical dams across the trenches. However, when it became apparent that the design of an adequate bentonite-shale mixture for surface sealing would not be completed in the very near future, the decision to use polyvinyl chloride (PVC) was made. The PVC sheet selected for this construction is 0.01 in thick and has an estimated life of 25 years. Also because of the ease in installation of the plastic membrane, it was extended from trenches 105 and 83 to cover trenches 72 and 69 as well (Fig. 43).

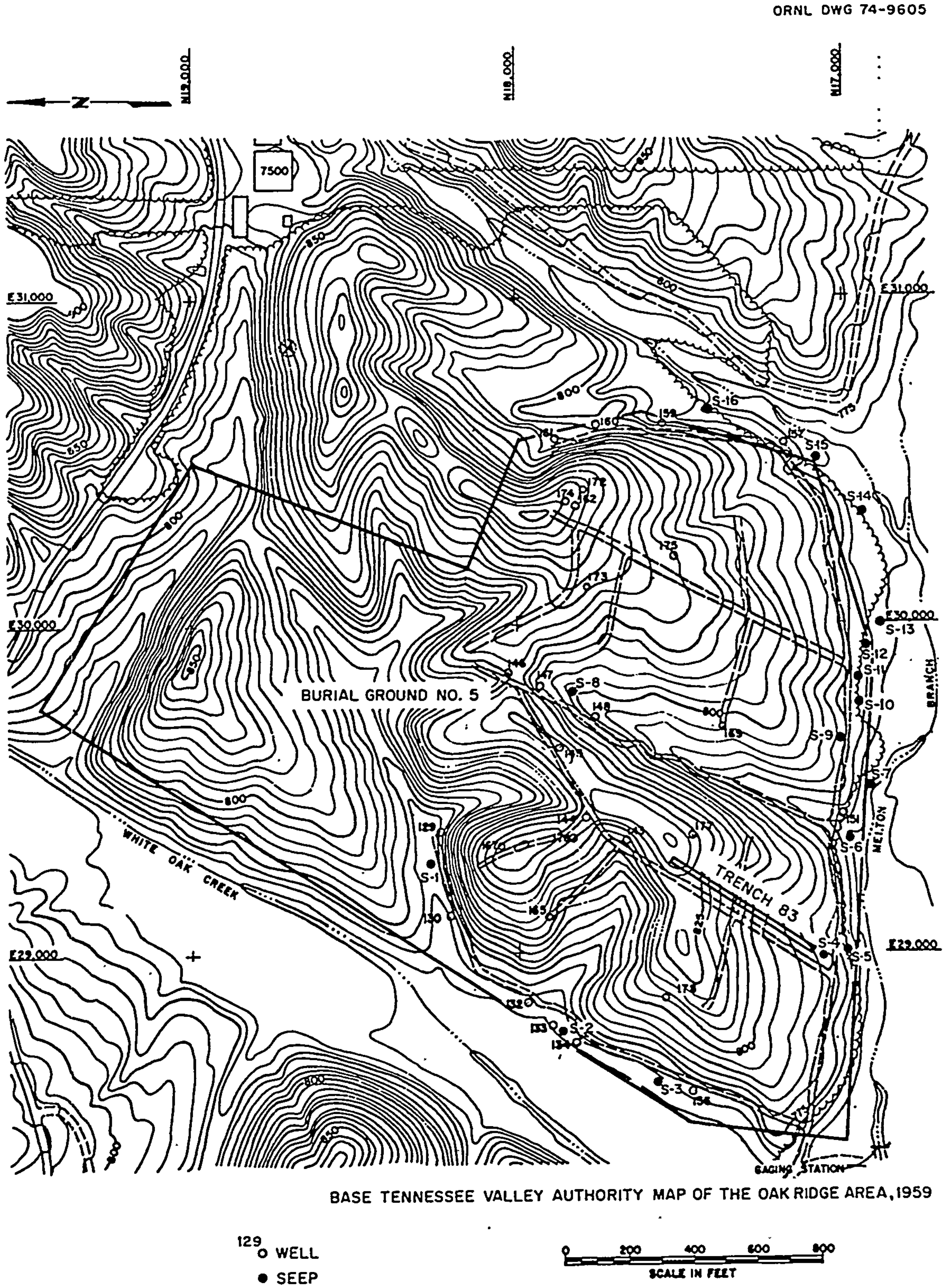


Fig. 42. Location of trench 83 in burial ground 5.

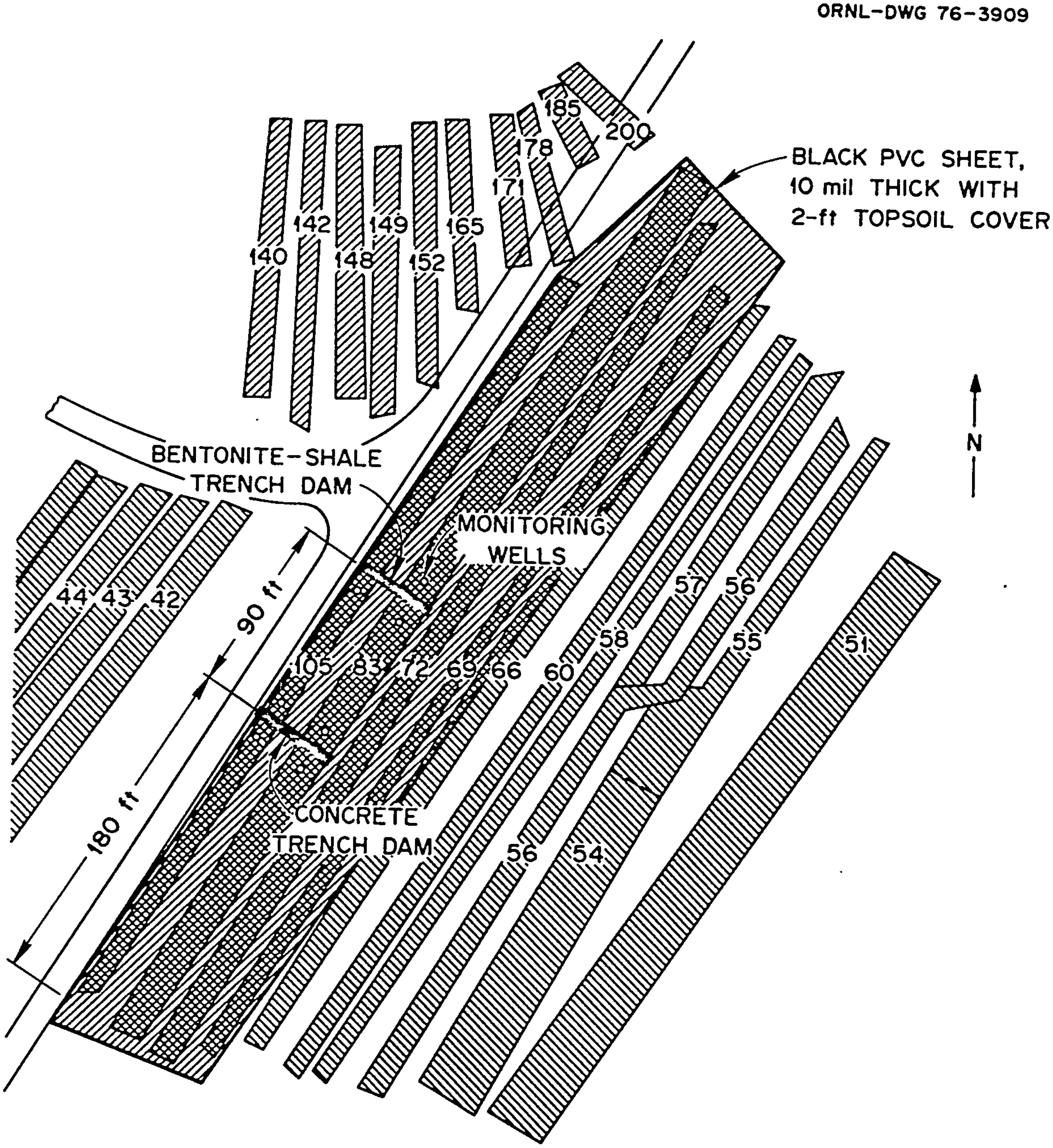


Fig. 43. Near surface sealing of trenches in burial ground 5.

The construction began in May 1975 when 2 ft of overburden were stripped from the area. After the overburden was removed, the trench for the lower dam was excavated. Approximately 3 ft of water was present in the excavaton. The amount of water added to the problem of obtaining an effective seal under the dam. To ensure a good seal, a precast concrete slab was used with a 25% bentonite-shale mixture (Fig. 44). Thus, as water seeps around the concrete, it will carry bentonite, which will eventually form a seal around the concrete slab. Also, a thin layer of pure bentonite was placed directly under the slab. The construction of the second dam was much simpler because no water was present in the excavation and the dam could be constructed of compacted bentonite and shale (Fig. 44).

After the two dams were completed, the area was covered with the PVC membrane, and the overburden (approximately 2 ft) was placed over the area. The area was then planted in grass to prevent erosion. The sealing was completed in September 1975, and monitoring wells were installed as shown in Figure 43. Monitoring wells were also installed in the lower ends of trenches 83, 105, 72, and 69. Data from these wells indicate that water levels in the sealed trenches during the past winter did not achieve the height necessary to cause trench overflow. The presence of water in the sealed trenches is attributed to a general rise in the ground-water table in the area and not from direct infiltration.

Other corrective measures initiated in burial ground 5 consist of surface contouring of the southeastern portion of the burial ground. In conjunction with the countouring, surface drainage ditches were also

ORNL-DWG 76-3908

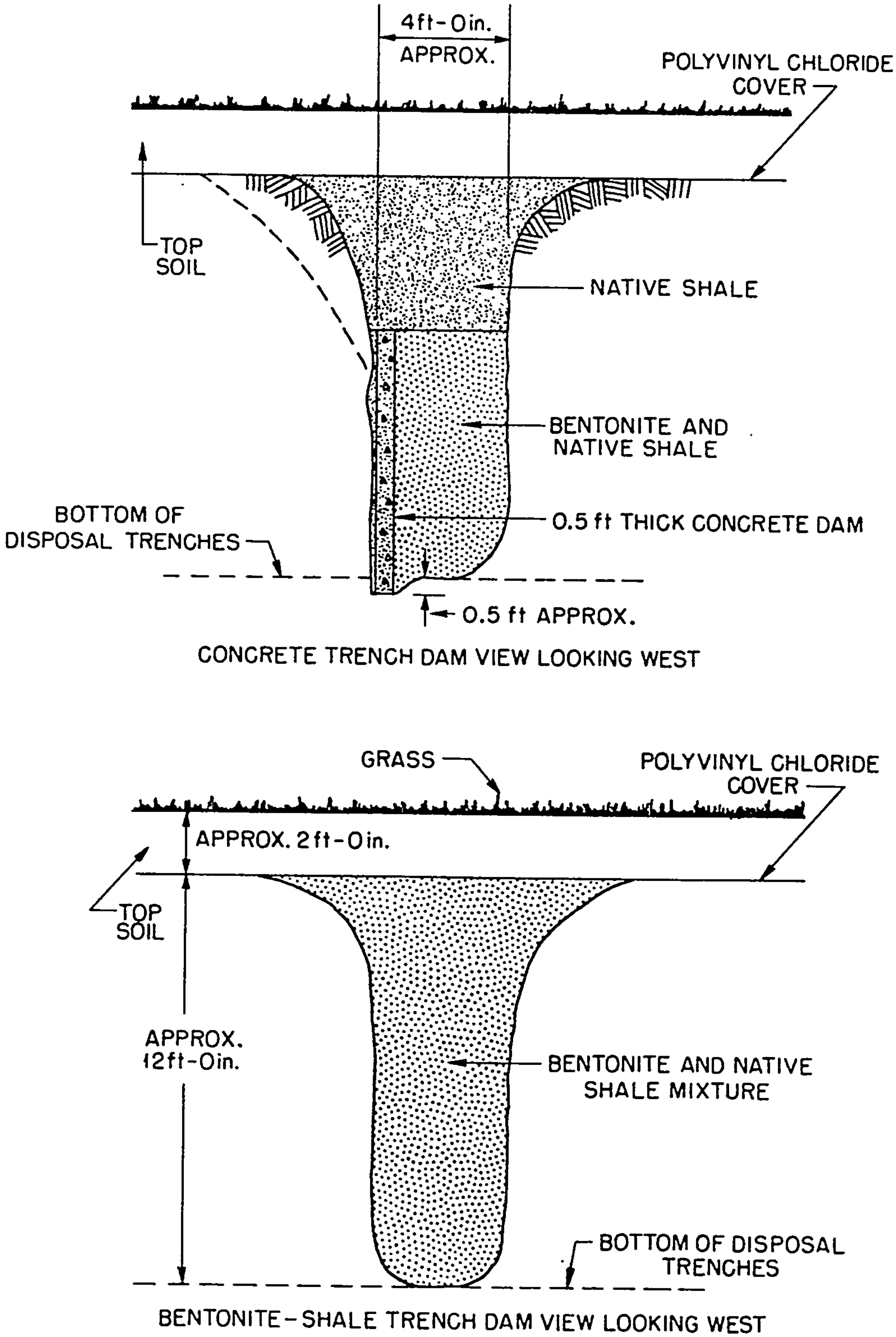


Fig. 44. Cross sections of concrete and bentonite shale dams across trenches 105 and 83.

installed; however, no detailed drawings of these improvements are available at this time. The results of these corrective measures can be seen in the reduction of ^{90}Sr discharge from the area in 1976 (see Table 8).

In 1974 and 1975 the practice of vegetation control on burial ground surfaces was begun. Existing trees on the burial grounds were cut, and periodic mowing of the areas to control the new growth of trees was initiated. This practice will prevent the growth of trees, which in turn could transport radionuclides to the surface (via transport from roots to leaves).

A second practice that was begun recently is near-surface sealing of new burial trenches (in burial ground 6 which is also in the Conasauga shale). The near-surface seals consist of a layer (3-4 inches thick) of bentonite-shale (15% bentonite) placed at a depth of two feet below the ground surface. The bentonite was spread on the ground surface using conventional farm spreading equipment, disked into the first three inches of the surface with an appropriate amount of water, and compacted to optimum compaction with conventional rolling equipment. The compacted bentonite-shale seal was then covered with two feet of soil and the surface was smoothed and seeded with grass. As yet, little instrumentation has been installed to measure the effectiveness of this seal; however, additional moisture meters will be installed in the near future. A comparison of the soil moisture above and below the seal and comparisons with moisture contents in unsealed areas should be a measure of the effectiveness of the seal. The ground-water level below the sealed trenches will also be monitored. To date two areas covering about 1.5 acres have been sealed in burial ground 6.

Studies are presently underway to obtain detailed information about the hydrogeologic conditions in and around the burial grounds, especially burial grounds 4, 5, and 6. Once the ground water system is better understood, appropriate technologies may be applied more effectively in the design of additional corrective measures to ameliorate the problems encountered during and subsequent to waste burial.

IV. CONCLUSIONS

Current solid radioactive waste burial and storage practices at ORNL do not have a serious impact on the quality of the environment or the health and safety of the public. Nor is there any indication that wastes buried in the past pose a significant hazard to the public. Nevertheless, there are areas where improvements could and are being made that will perhaps help improve confidence in radioactive waste management operations.

Perhaps the most visible deficiency is the slow leakage of activity from the burial sites. Even though the quantity of released contaminants is only a fraction of a percent of currently accepted standards (in the Clinch River), it nevertheless provides an area that critics can point to to suggest that ERDA is not properly managing its own wastes. The location of ORNL in an area of high annual rainfall and numerous nearby streams, rivers, and lakes, presents a more difficult water management problem as it relates to solid radwaste operations than is faced by most other ERDA sites. A compensating factor is the character of the soil (weathered shale) that exhibits a very strong affinity for most radionuclides, thus greatly reducing migration in the ground water. This has been demonstrated by the very slight movement of radionuclides from liquid waste seepage pits in which over a million curies of activity was deposited during the first twenty years of operations at ORNL until the practice was discontinued in 1966. These abandoned seepage pits are in the same general area as the solid waste burial grounds. The current program, started in 1973, to identify areas of leakage and test various corrective measures should be continued uninterrupted because changes in ground water movement or water table levels occur very slowly, and it may be a year or more before the effectiveness of a particular measure can be evaluated.

The practice of above-ground storage of contaminated equipment in SWSA-3 is another area where there is no indication of adverse effects but which presents the appearance of slip shod attention to the handling of contaminated materials. The vast bulk of these items have been in SWSA-3 for many years, rusting away, and obviously will never be used again. Because these items are scattered all over the burial ground, it is not possible to mow the grass and weeds which contributes to the unkempt appearance of SWSA-3. This problem may be extended to SWSA-6 if ERDA continues with its plan to require that contaminated metal items of waste that may eventually be suitable for volume reduction in a smelter be stored aboveground rather than buried. If this practice is to be followed, then storage buildings should be constructed for this material.

The present ERDA practice of programmatically funding burial ground operations rather than having the costs allocated to a large variety of Laboratory R&D programs has resulted in a significant overall improvement in burial ground operations. Under the present system it has been possible to prepare a systematic plan for each year within a defined budget justified to people who are knowledgable about the costs and needs of radioactive waste management. Under the old system of allocated costs, it was frequently difficult to get funds for upgrading facilities and operations because the funds would have to come from other R&D programs. Some of the operators of facilities generating TRU wastes at ORNL are having difficulty in obtaining GPP funding for facilities to aid them in segregating wastes at the source because of the competition of R&D type GPP funds. It would be helpful if the use of DWPR GPP funds, currently restricted to burial ground improvements, could be extended to include waste segregation facilities at the source.

The current practice at ORNL is to bury wastes at depths up to 1 ft from the highest known water table level. This practice has been questioned by some people who have reviewed our burial ground operations, and it has been pointed out that the State of Tennessee law requires that buried wastes be 10 ft above the water table. Under the current practice, there are about 33 usable acres within the 68-acre area of SWSA-6, and it is expected that this will serve the needs of the Laboratory for fifteen to twenty years. However, if there should be a significant change in the water table separation requirement, the usable area would be greatly reduced and work would have to start immediately on developing another burial ground area. This process would take about two years, and it appears that the new burial ground would have to be in Bear Creek Valley since there is insufficient suitable acreage left in Melton Valley. If the Solid Waste Handling and Decontamination Facility is built and goes into operation in 1983 as currently planned, acreage requirements will be greatly reduced and SWSA-6 may last for many more years. The low level Solid Waste Compactor, scheduled for operation late this year should also reduce future land usage.

Although ORNL has maintained radiation monitoring stations on White Oak Creek and Melton Branch for many years, there has probably been an inadequate radiation monitoring program within the burial grounds to give warning if there is activity migration from burial trenches. There were a number of monitoring wells in SWSA-5 and -6, but most of these were destroyed during the course of burial operations and there was no systematic sampling program. This deficiency is currently being corrected by the installation of a water-table level monitoring well network in SWSA-5 and -6 under the direction of the USGS on-site consultant who has been reviewing our burial ground monitoring practices. It is also planned to install a few wells in the old burial grounds.

The practice of burying general radwaste with no compacting other than the weight of the overburden is wasteful of land area and probably enhances water infiltration through the buried waste. As noted previously, a waste compactor for low radiation level wastes is expected to be in operation this fall. By volume, approximately 80% of the wastes currently being generated are low level and, of this amount about 70% is of a compactable nature. On a longer term basis, current plans are to have an incinerator facility for this type of waste by FY-83.

Not enough is known about the rate and direction of ground water flow under the ORNL burial grounds. A program to correct this deficiency is currently being conducted by the USGS consultant and the Environmental Sciences Division.

ORNL is not in complete compliance with ERDA Manual Chapter 0511 which requires that retrievable type wastes be segregated into burnable and non-burnable fractions. As noted earlier, some facilities which generate TRU-type wastes were built before there was a separate category for this waste. They do not have sufficient space to carry out a sorting operation, and there is no central facility to which the waste can be sent for sorting and repackaging. Better sorting of the low radiation level TRU wastes will be possible when the proposed Solid Waste Handling and Decontamination Facility is built.

The volume of TRU-type waste going into retrievable storage is probably larger than it has to be because of the lack of a method of assaying the wastes. The current practice is to assume that all waste from certain facilities is above the 10 nCi/g retrievability limit and place it in retrievable storage because of our inability to easily determine its contamination level. A study of the problem by the Instrumentation and Controls Division indicates that currently used assay systems such as that at Los Alamos will probably not be suitable for most of our TRU wastes because of its highly variable nature and the predominance of fission product activity. It is planned to construct an assay station in FY 1978 in SWSA-5 and, by modifying currently available instrumentation, try to develop a means of screening at least some of the incoming TRU wastes.

Burial ground operations can continue without any significant change in procedures for the next three years without adding in any significant way to existing problems with respect to public safety and environmental pollution. Indeed, it will probably not be possible to evaluate the effectiveness of some measures currently being taken such as annual surface sealing, etc., for three or more years. The current programs to upgrade monitoring capability and better understand hydrological conditions should, however, continue during this period.

Finally, the whole practice of shallow earth burial of contaminated wastes in the Oak Ridge area should be re-examined. The feasibility and costs associated with transporting these wastes off site to a more suitable environment for burial or storage should be studied. As a part of this re-examination, the possibility of segregating wastes into fractions which can be buried at ORNL and those which should be buried elsewhere should be considered.

V. RECOMMENDATIONS

1. Recommendation: Prepare a hazards analysis with respect to possible long-term effects of burying general radwaste only 1 ft above the high water table.

   Estimated Cost: 1/2 MY, $25,000.

   Justification: Our current planning assumes a minimum of 15 years additional life for SWSA-6. If it appears that a significant change should be made in the current practice then planning will need to be adjusted accordingly.

2. Recommendation: Continue with the current program of installing monitoring wells within the burial grounds and institute a formalized program of systematic sampling of of the water in these wells.

   Estimated Cost: $200,000.

   Justification: By building up a historical record of radioactivity levels in the ground water in various areas of the burial grounds, we will be able to spot changes that may indicate a need for corrective measures.

3. Recommendation: Upgrade and expand the water and sediment discharge measuring capacity of monitoring stations 3 and 4.

   Estimated Cost: $750,000.

Justification: These facilities should be capable of measuring much larger values of streamflow and collecting accurate flow proportional sediment samples. This capability would provide data necessary to evaluate radionuclide discharge from burial grounds during storm events, quantify hydrologic transport of radionuclides in surface waters, estimate contaminant releases at White Oak Dam (station 5) when flow is too great to monitor with existing system, and assist in evaluating the effectiveness of corrective measures applied to the burial grounds.

4. Recommendation: Provide storage buildings for materials being held for future smelting.

   Estimated Cost: $500,000

   Justification: These buildings would provide protection of these materials from being stolen and disposed of by persons who are unaware of the potential hazard of the contamination.

5. Recommendation: Installation of corrective measures designed to reduce radionuclide discharges from burial grounds should be continued.

   Estimated Cost: $500,000/yr installation and $250,000/yr research.

   Justification: The reduction of ^{90}Sr discharges to the Clinch River.

6. <u>Recommendation</u>: Detailed investigations of the current status of the radioactive inventories in seepage pits and trenches and in settling basins should be initiated.

   <u>Estimated Cost</u> : (?)

   <u>Justification</u>: To evaluate the current and estimated future discharges from these inventories.

7. <u>Recommendation</u>: Study alternatives to shallow earth burial at ORNL.

   <u>Estimated Cost</u>: 2 MY, $100,000.

   <u>Justification</u>: Current studies of shallow earth burial may indicate that burial in a climate similar to that in Oak Ridge should cease or the cost of precautionary measures may be high enough to make shipment off-site a more attractive alternative.

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